Computational Sustainable Architecture/Informed Morphology

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READING THE THESIS

The work presented through this thesis is of successive character by parallel paths in theory and exemplification (ill.001) to which argumentation, suggestions and definitions are presented. Two constituents, a) theoretical part and b) design part, construct the project. The theoretical part elucidates digital definitions, formulates processing concepts, a merge of scientific disciplines and a series of methodological operations to create an architectural framework with the title computational sustainable architecture.

The second part of the project is a prolongation of the framework developed in the first part through a design project, in which the research conducted is applied. The second part is thus a design entity with the title Informed Morphology. The framework in the first part enables an infinite series of architectural sustainable solutions according to the use of suggested process, knowledge feed and operations.

Though reading the paper in a linear path, it is recommended to take use of appendix information for explanatory notes and an extensive amount of design data. Description of appendix data is placed at p. 236.

Ill. 001

Theory and practice are presented together to complement each other. Some examples have a general importance for the described subject, whereas others are implemented for a particular element of the example. The illustration tries to size some of the examples according to their relations to the subject. Illustrations close to the theoretical line have more general relations to the subject treated.

I. PREFACE

Computational and sustainable strategies and spheres are bridged to create a framework for explorative environmental architecture. The thesis explores among others methodologies, creative cognition, architectural operations and sustainable strategies through theory, exemplifications, case studies, experiments and finally a pilot project.

II. TABLE OF CONTENT

III. MOTIVATION

Three primary positions are the motivation for the path of this project. They are as such singular entities but in my perspective interwoven and the starting point when searching for innovative environmental design solutions.

Dynamic static's

It is a peculiar constellation of contradictions and a problematic dimension in architecture. Nevertheless is architecture in reality of static kind and everything that surrounds and inhabits it is dynamic. Lateral human flow, fluctuating weather and time in its simplicity are all influencing elements in the lifespan of a building. The search here is not for utopian kinetic solutions, but the incorporation of dynamic parameters in static performative form. Greg Lynn describes our hanging behind in the architectural comprehension of form:

"A boat hull does not change its shape when it changes its direction, obviously, but variable points of sail are incorporated into its surface. In this way typology allows for not just the incorporation of a single moment but rather a multiplicity of vectors, and therefore, a multiplicity of times, in a single continuous surface."

[Lynn 1999:p.10]

Unreleased power

It is frightening to see how much use of the computer we do within the complex, multidisciplinary field of architecture, without really using it. The potentials of the machine when it comes to speed are enormous, being able to redraw scenarios infinitely faster than the human brain. Its capacity together with the designer to create sophisticated, performative solutions is emerging, unfortunately to a limited degree within sustainable architectural design.

"Beyond the fact that over the past decade a new generation of avant-garde architects is pushing digital technology to its limits, so far it has had relatively little qualitative impact on the profession of architecture at large. In general, information technology has improved the efficiency of designing buildings, when in fact it has the potential to reinvent the architectural process itself".

[Kalay 2004:xvi]

Sustainability

The term itself reveals the approach. Little doubt is there to the necessity of architects taking measures on this subject. The possibilities of exploring in fields normally not seen in corporation with architecture fascinate and offer new perspectives on design solutions and their processes. Sustainable design in its splendour is often the product of intuition and logic, a merge of disciplines.

IV. INTRODUCTION

A short brief

A change over night. That is what seems to have happened when discussing the approach to environmental issues. In all industries, led by the automobile companies to small software developers via governments the concern of a 'green image' is vital [Nørretranders, 2006]. This trend is a healthy one, but also necessary if looking at the facts that the Intergovernmental Panel on Climate Change (IPCC) put forward to show the conditions of a bleeding Earth [IPCC, 2007]. Primary pollution sources have been attacked from the public domain, criticising mainly the car and aerospace industries for their ignorance concerning environmental issues and their sole capitalistic strategies. Now, there is a good business in environmental solutions, hence the industries are changing approach. However, the turnover in the state of the planet, described by IPCC and others, cannot only be done by the transport sector – not even close, when looking at the numbers of energy consuming sectors. The building industry marks its environmental footprint in an increasing tempo as cities continue growing, creating a linear process of waste production and energy use. Approximately 70% of all waste derives from cities and return into the biosphere untreated [Battle, 2002, p.36].

"In the United States commercial and residential building consume close to 40% of our total energy, 70% of our electricity, 40 % percentage of our raw materials and 12 % of fresh water supply. They account for 30% of greenhouse gas emissions and generate 136 million tons of construction and demolition waste."

[Autodesk Revit White Paper, 2005]

The respond

The undeniable reality of the building industry being a huge contributor to a catastrophic energy use has enforced governments and greater forces like the EU to react, demanding lower energy consumption and improved indoor climates, creating a sustainable profile. Course of action are manifested in the Kyoto protocol [wikipedia.com], which act as guidance for governments and thereby the practising architects, engineers and contractors. The growing awareness has led to strategies of the reduction of toxics, waste and energy consumption. Concepts like the 'Passiv Haus' developed in Germany and Austria [passiv.de] is fastly gaining grounds in Europe, with its 'easy to apply' principles to traditional architectural design and processes, while other European nations like Denmark have imposed energy classes [sbi.dk] that must be reached for the design to be approved for construction. The first approach list components, materials and standards to obtain a certain energy consumption level, while the latter model sets energy consumption rates to be fulfilled freely by the designer. Both ideas of sustainable implementation into architecture take its offset in traditional building culture, which is evident in the realised projects [Wines, 2000:p.11].

Another approach?

The turn in contemporary architecture towards a more 'human' footprint of the built envelope are in many cases done with the same reasons as the car industries, 'to keep the wheels running'. It is a strategy to adopt the ecological trend out of necessity. It becomes a way that the framework of architectural practices has adjusted the existing traditions of design-

ing, rather than an actual fundamental change in the way we think of sustainable architectural design [McDonough, 2002]. He adds,

"But is being less bad the same as being good? Does mere efficiency meet our need to connect with the natural world or does it just slow down ecological destruction? And if sustainable architecture falls short of fulfilling our needs, what would sustaining architecture look like?"

[McDonough, 2002, p. 8]

With this lies an important point of departure for designers in the aim of sustainable architecture that not only fulfils the requirements put forward by the authorities, but instead are in search of human habitat enriching the surroundings with its presence. This represents a completely different approach than the one practiced in the recent decades and demands new investigations of the architects and the engineers. Political, economical, social and cultural forces are with the changing focus, despite the reasons in many cases being of financial character, in a position to suggest a better relation to our environmental context. The paradigmatic change gives architects, engineers and their associates
a significant chance to revolutionise through their unique relationships to place, human habitat and knowledge of technological, social and cultural aspects. To accomplish better solutions it is in general, and perhaps especially within sustainable architectural design due to its connection with fluctuating parameters – the weather, essential to not only focus on the built projects, but instead concentrate on the processes behind as they reveal the intentions, strategies, principles and team constellations in their raw form explanatory for others to learn and improve from. With such complex matters as a performative sustainable architecture, systematic and mechanic skills combined with intuitive and spontaneous operations, can envision innovation. The two poles of stereotypical players, the engineer and the artist [Lawson, 2006] in a team or as one person are in possession of solving the above-mentioned problem, by enabling a logic and intuitive approach simultaneously. This approach is seen fundamental to the achievement of improved sustainable design.

In addressing this issue, one must be aware of the state both architectural fields, sustainable design and digital design, are situated in. New generations of digital tools emerge rapidly in contemporary architecture, while the agenda of environmental issues gains strength from day to day, forcing an environmental design renaissance. This turbulence without a theoretical foundation or practical frame of an architectural ideology gives the possibility of architectural exploration, as at the same time disabling designers to use digital sustainable design processes due to their complexity of comprehension and use.

To improve the implementation of sustainable strategies on higher complexity constellations than traditional Euclidian geometries to preserve design freedom in performative architecture a new methodological approach might be necessary. Potentials of the computer have in its resources the basis for reinventing the architectural process, as described by Kalay. This becomes the offset in determining the path of investigation throughout the project.

V. AIM

Scope/Objective

A theoretical and methodological framework that constructs a base for implementation of digital design tools and processes into sustainable architectural design, seeking to improve performance of energy consumption and thermal conditions in architectural form, are the main objectives of the research and praxis of this work. Focus is placed on early design phases to alter the foundation from which sustainable design derives[1]. In the path of this goal lies exploration of generative form-finding tools, performative analytical simulations and the iterative processes that frame novel contemporary projects.

Limitations

A limitation of technological constructs are set to the level of programming individual pieces of software as plug-ins for already existing commercial releases of parametric/associative software as it lies outside the scope of the project. Nevertheless are 'practical' experiments in digital environments seeking to customise solutions via generative applications.

Description of problem

How can environmental sustainable architectural design advance its performative solutions through the resources of computational technology and digital design processes?

Design intent (second part)

The design intentions are consequently a prolongation of the theoretical work and implemented experiments to verify the suggested processes, methods and architectural components. Advanced technology and passive techniques and strategies are seen as main ingredients to reach a site-specific, performance optimised and sensual building responding to geographic location and culture and the composite demands of authorities and the public. The project thereby taking part in the ongoing discussion of how to deal with the apprehensive situation of the environment as a design solution with respect to the process and product developed. Through this the project offers a way of creating digital sustainable design. Looking for untraditional processes that are made capable through avant-garde technologies, iterative methods and the surrounding world which architecture must live in and learn from.

VI. METHODOLOGY

Theoretical path

The thesis firstly introduces digital implementation (Digital definitions chapter) in architecture to elucidate the potentials of use in sustainable design and to clarify the digital contribution and evolution of architectural language and processes. This includes the classification in theoretical thinking of digital design, which is by technological interventions constructing new paradigms in architecture, which the following work will derive from.

To understand and create a foundation for definitions of computational sustainable architecture an investigation of digital design processes, parameters, knowledge and projects is following through theory of architectural processes and case studies (Processing chapter) to formulate a progression path.

The search and idea of merging sustainable design and digital design offers further research in hybrid constellations which seeks to suggest that the combinations of dichotomy perspectives enrich process and final product informing a differentiated architectural approach from opposing knowledge levels and knowledge spheres (Merging chapter).

On the basis of analysis, theory, knowledge and formulated schemes and definitions in the prior three chapters, methods are presented, offering operative suggestions to conceptual form finding (Operations chapter), which summarise the work presented into a gathered framework for computational sustainable architecture.

Case investigation

In architecture, investigation is often conducted in both theoretical and practical cases. Research by the study of projects offer a quantitative and qualitative analysis [Flyvbjerg, 1991] of parameters inflecting the topic and is thereby highly usable in the search of specific influencing principles in computational sustainable design solutions. In this work empirical studies are conducted by the analysis of specific sustainable elements, being

[1] Implementation of solar energy
[2] Use of wind
[3] Spatial organisation
[4] Material interventions

And process factors

[5] Level of computation
[6] Level of cross-disciplinary designers
[7] Phase constellation

And a comparison

[8] Summary / Evaluation

Though the study is non-objective by theory of research methods, it is still found to construct a base for objective argumentation when arguing the definitions of computational influence and potential. The interpretation of process as phenomena is accessible through case studies [Flyvbjerg 1991] and becomes thereby an important tool in dissecting the digital potentials for improvement of sustainable design. To obtain convergence without inflecting boredom on the reader, few, but qualitative examples are chosen for analysis.

As sustainable design and digital design is in its early stages of development and even less existing in realisation, few examples directly applicable for the topic researched are accessible. Leading practices known to bridge architecture and engineering have nevertheless performed processes of applied digital design tools into sustainable architecture.

[1] Foster and Partners/Swiss Re/London (Processing chapter)
[2] Foster and Partners/London City Council/London (Processing chapter)
[3] Grimshaw/Fulton Street Transit Centre/Fulton (Processing chapter)

Experiments

Operational tools are developed through different sustainable strategies. The idea/aim of conducted experiments is to isolate singular conceptual ideas to offer further creative implementation into holistic sustainable solutions, rather than to solve complete building problems. By this method a small series of computational sustainable concepts are constructed with diversity in use, complexity and building scale. The successive experiments in regards to level of complexity in development and implementation are described by strategy levels.

1. Strategy (associative surface with parametric constraints to openings in the surface)
2. Strategy (associative volume with parametric constraints to shading control)
3. Strategy (associative surface/volume with parametric constraints to solar penetration. The generative model is simulated with thermal software to test the effect of the constraints from the parametric model)

Though the strategy levels are being of successive character, the rise in complexity from one experiment to the next cannot be compared to the one prior or forthcoming as the variation of sustainable conceptual idea, parametric input, simulation methods and detail level are of significant difference, despite being described through the same evaluation points. The experiments can in this way be seen as individual architectural elements, being analysed and activated for abstract or direct implementation into architectural solutions.

[1] Aim
[2] Concept
[3] Architectural element
[4] Parametric constellation
[5] Sustainable potentials
[6] Process potentials

Emergent technologies within generative form finding can be applied into sustainable thinking, given technological basis for the experiments. The chosen application for use is Generative Components, created by Bentley Systems. The associative/parametric modeller is chosen due to its compatibility with computational fluid dynamics software and thermal software, though with limitations. It furthermore offers operation on three different levels: modelling, scripting and programming. For thermal and solar simulation Eco-Tect, by SquareOne, is used as being a programme developed for architects, rather than engineers. This is important, as the idea is to create tools/methods usable for architects in form finding processes. The software offers various light studies and thermal and acoustic simulations.

1.0 DIGITAL DEFINITIONS

Digital classifications

Representation	Creating form		Interactive and optimisation	
CAD models	Formation models	Generative models	Performance models	Compound models
	Topological formation	Shape grammar	Formation models	
	Associative formation	Evolutionary models	Generation models	
	Motion based formation			

Ill. 002
CAD models represent the common use of computers today as a drafting tool, whereas the remaining models incorporate different levels of computation.

Digital ideology and the theoretical thinking of classifications are still in its evolution and a precise systematisation of digital architectural design may still lie ahead, though writing on the topic has exploded over the recent years. Oxman, 2005, formulates a holistic classification of the digital design process, trying to grasp the contemporary and seeking to think of the future based on observation and theory. It describes different technological and operational processes that enable the designer to create through different methods [Oxman, 2005:p.246].

The classification systemises the different ways in which digital design is understood and used in architectural processes and can thereby give an understanding of the various tools accessible for the development of a formulated methodology in computational sustainable architecture.

Definitions are illustrated to clarify the position in digital design evolution, visualising a growing complexity of informed models. Subclasses identify the specific operational methods and illuminate potential use for various design approaches. A threshold into computational design can be set between CAD models and Formation models due to a shift from computerisation[2] to computation[3]. Explanation of this proclamation is made clear through the description of the models below.

A. CAD models

CAD (Computer-Aided-Design) models are developed as a tool of representation for drafting and visualising ideas, much like pre-digital paper based representations of form. This form of digital extension has little effect on the development of architectural solutions [Kalay, 2004] as manually input constructs known outputs and gives linear progression similar to a traditional architectural process. An opening towards a change of linearity is though achieved among others by Frank Gehry and Partners, as they operate with the analysis of physical models to construct digital and visa versa creating a dual-directional process path between the two medias – digital and analogue.

B.

Formative models

The definition of formative models cannot be simplified into a single unit and is thus described through three formation terms; topological, associative and motion-based.

B1. Topological formation

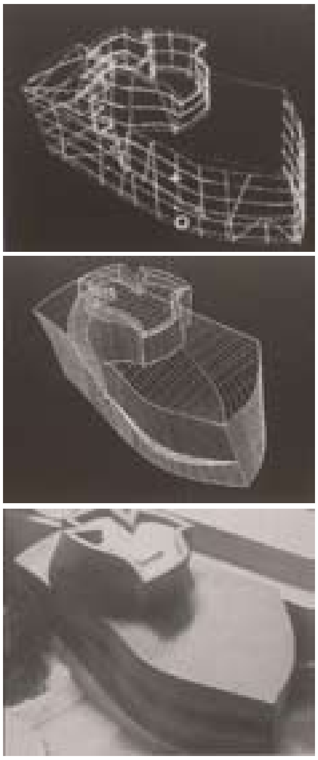
Topological formation can be seen as an alteration of form without changing the geometry constructed [Kolarevic, 2005]. This is a way of deforming shapes, often forming curvilinear expressions using NURBS[4] (Non-Uniform-Rational-Bezier-Spline) that enables the designer to fluidly change expressions via control handles. Non-Euclidian form languages are then produced, as a deformation of Euclidian shapes is developed instantly by using NURBS commands such as surfaces and curves. Forming or deforming topology is often non-Cartesian relations, working in dimensions of U and V[5]. With the arrival of curvilinear working environments, new architectural terms have surfaced, such as morphology, hyper surfaces, blobs etcetera.

Description of the model is often implicit and handled with deformations in the same way as a physical model is moulded, though with different constraints as natural forces (gravity, wind, varying vertical loads etc.) normally are non-existing in 3D modelling. Workflow is thereby based on trial-error attempts by visual criteria's meaning that a shape is selectively constructed and afterwards altered to fit the wanted form.

B2. Associative formation

Designing in associative environments is a way to construct 3-dimensional models via explicit commands. Linked relations, control points, lines, surfaces, volumes and times enabling the designer to handle complex geometry to a new extent. Alteration in geometry is as the name presents associating alteration in the rest of the shape, making it possible to redraw design schemes many times faster than with previous 3-dimensional modellers. An unlimited number of data/parameters can be fed into the systematic relations constructed for performance optimisation and development of form through both knowledge and intuitive design wishes. New technologies are until now only accessible through a few modeller packages. It nevertheless offers endless opportunities as the software operates with several depths of

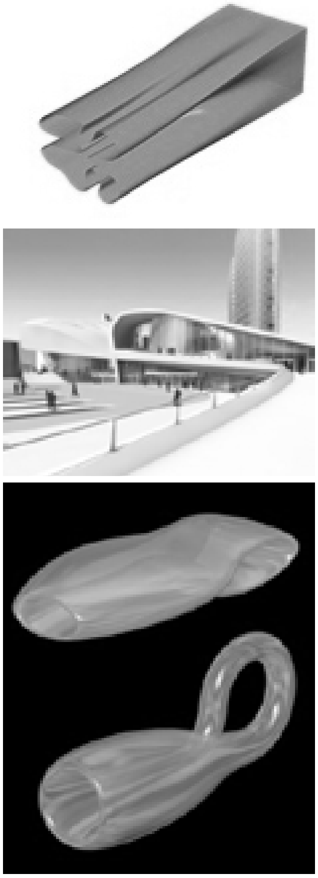
Gehry and Partners
CAD models



Gehry and Partners are recognised for their use of digital tools to manufacture complex geometries, however still designed through traditional use of computers.

Ill. 003

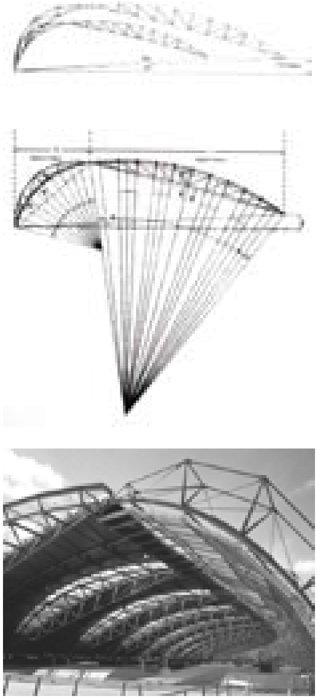
UNstudio
Topological formation



Topological software enables UNstudio designers to warped spaces, creating spatial continuity, represented in the Klein bottle, and incorporated in the Arnhem Station in The Netherlands.

Ill. 004

Grimshaw Architects
Associative formation



Geometrical relations construct associative geometrical modelling, represented through the system setup design by Grimshaw for the Waterloo station, United Kingdom, as a respond to a complex changing curvature.

Ill. 005

reconstructing the geometries as scripting and programming is allowed within the software, giving an open source structure letting designers go beyond the limitations of geometries set by the programme. Parametric constraints can individually be assigned to a model altering the form automatically when rules are changed. Generative systems are then altering the creative output parallel with the changes of the designer.

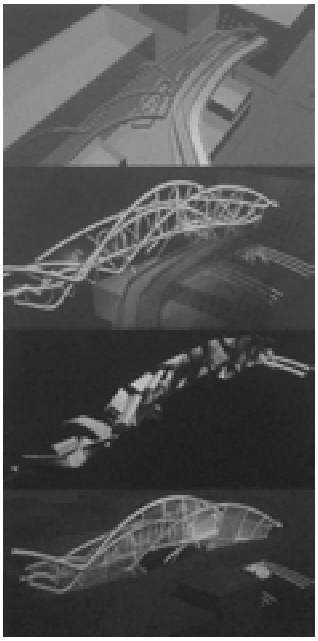
B3. Motion-based formation
Time becomes an important factor using motion-based design utilities borrowed from filmmaking software packages. A clear distinction from conventional architectural practice is taken by looking at dynamic environments contrasting to static environments in which many projects are conceived. It is an approach where formation is conducted by motion over time, influenced by applied dynamic parameters as force fields and kinematics. Greg Lynn[6] being the father of this methodological approach has envisioned several projects based on particle emission developing a form language of dynamic nature responding to site information's as sound, flow of traffic etc. When the design engine has started, the designer chooses a frame of the animation in which form wishes are satisfied. The animated models are therefore constructing shape with very little interaction from the designer. Though one must acknowledge that the architect constructs input data for the transformative process.

C. Generative models
Rules, relations, principles and orders are in this model essential to the development of form. Complex mechanisms are conceived by mathematical notations and controlled by algorithms. Through the construction of generic algorithms grows patterns and shapes with various outcomes according to the interaction of the designer by alteration of relations. So far, two distinct ways of constructing generative models can be defined: shape grammars and evolutionary models.

C1. Shape grammar
Mathematical expressions construct mechanisms for computational form finding. Emergences of design in geometric relations are optimised structural systems and complex material behaviours as tiling, fractals, spiralling et al. Design processing is in this approach predefined explicit rules that generate a series of possible solutions.

C2 Evolutionary models
Genetic codes drive algorithms constructing evolutionary models. It is mainly incorporated into architecture through research programmes to create systems reacting to the surrounding environment. As in natural evolution, the development of a species is the adaptation to place, much similar to human habitat [Menges and Hensel, 2006]. Morphogenesis[7] in digital design can then be seen as a way to adopt behaviours to contextual elements by evolutional codes. Oxman describes the shape grammar and evolutionary models as the models of most potential within digital design [Oxman, 2005:p.257] as they push the boundaries into emergent technologies developing solutions far further than prior possible.

Greg Lynn Form
Motion based formation



A series of motion particles react to a kinetic environment, creating a force field developing the trajectories of the bridge.

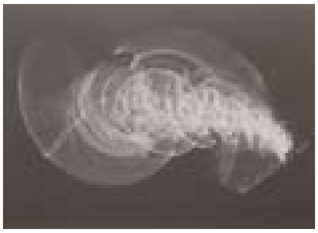
Ill. 006

OCEAN NORTH
Shape grammar

Shapes with grammar, creating generative systems, develop various geometrical compositions according to information feed. The shape and grammar are reconfigured according to design wishes.

Ill. 007

Karl Chu
Evolutionary models



Evolutionary algorithms based on L-systems, generate an organisation similar to plant structures, hierarchies, densities and connections.

Ill. 008

D. Performance models

Some projects seek to optimise structural composition, environmental features and thus construct performance models to develop form by the criteria. It is essential to understand this model as a way of generating form according to criteria and not to simulate form to evaluate.

D1. Performance based formation models

Simulation parameters drive the development of form by its analytical scheme. This means that the shaping occur to the understanding of forces attacking the design before actually designing letting the analysis construct the fundamental form. Through iterations of computational analysis and architect an optimised design is developed.

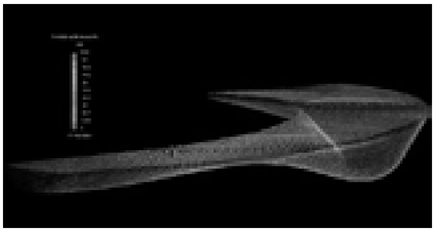
D2. Performance based generation models

A model linked to various environments, being of visual, analytical and parametric constellation is constructed to loop iterations from performance analysis to design intent generating a system upon which a continuum of solutions are tested. The form engine is thereby driven by performance data, driving a form generation, driving a simulation and so on.

E. Compound models

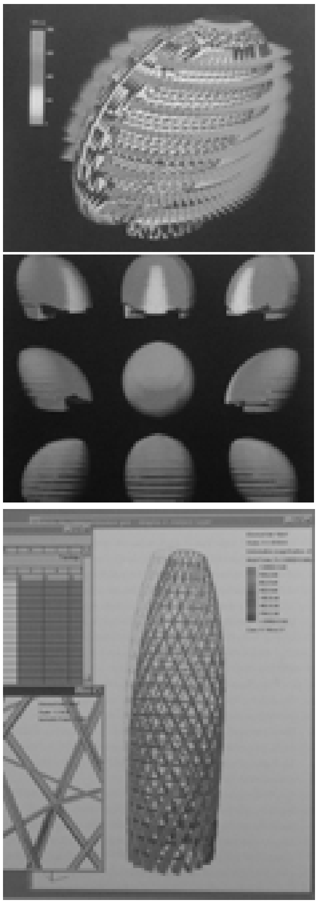
Future digital environments are imagined as integrated compound systems in which all types of data can be induced, simulated, modified, optimised and finally generated for the individual design intent. This is yet not possible, despite the introduction of BIM (Building Information Modelling). However, the larger commercial software packages are working towards that goal via common transfer formats as IGES, IFC, STEP[8] et al.

Shea
Performance based generation models



A continuous optimisation loop between structural forces and design is created through a simulation-modelling loop. Conditions are created from the designer, to which a finished solution will emerge.
Ill. 009

Foster and Partners
Performance based formation model



Various simulation environments give explicit performative feedback in shared data sheets or as false colour codes. Both the SwissRe building and London City Hall was created through simulation data.
Ill. 010

1.1 Depicting domain

A categorisation of digital design as classifications and definitions is obviously for discussion, being in process in contemporary architectural explorations. The above shown theoretical framework demonstrates various generations of digital design, but not a holistic image of digital implementation into architecture. Physical presence is not a certainty within the term digital design thinking of both process and product. It may be that digital architectures live more in the realm of the virtual environment, in which it is created. Interactive, virtual, informational and collective are some of the offsprings from digital design living beyond buildings that often inspire projects for realisation, such as art, sociology, technology, philosophy, mathematics et al normally effect architects in their work. Several projects constructed through Motion-Based formations are in the work of Greg Lynn seen as utopian or purely research based with the aim of discussing paradigms of architecture [Lynn, 1999]. Furthermore have digital-virtual projects like the Virtual Museum imagined by Asymptote developed discussion fora for the human existence in non-places and rethinking of the way information and media is experienced and distributed effecting contemporary design schemes towards new approaches to spatial definitions. A magnitude of unrealised digital projects explores potentials in new frames, when design is isolated from natural or human constraints [Yu-Tung, 2007].

In the perspective of the project scope, virtual architecture has little direct influence on the development of a methodology, as sustainable architecture should be a 'product' of physical contextual parameters [Wines, 2000] and hopefully a habitat for improved living conditions. This does not necessarily exclude virtual process adventures such as abstract spatial or material relations, but is nevertheless bound to return into reality upon verification of sustainable design in physical form. Certain criteria's can then be emphasised as foundation modules in the work to approach a new operational path towards computational sustainable architecture.

Asymptote
Virtual Museum

Ill. 011

The Virtual Museum created a wider discussion of digital implementations in architecture which gave birth to a series of experimental ventures, which became a larger part of form finding processes on conceptual level.

1.2 Platform

Distinguishing a particular digital class in order to use its 'normal' ways of development in architecture into sustainable design can be restrictive in the search for a new methodology. It nevertheless offers grounds for a continuing research for merging computational tools and environmental strategies in conceptual design phases. Due to the description and definitions of various digital approaches in the last chapter a selection of digital paths can be chosen based on the performance, process and desired end result.

Performing form

When looking at the theoretical defined models above it is obvious to take use of the performance models suggested. The driving factors are in this work sustainable parameters, which directly or indirectly provoke form development. Motion-Based formations, such as particle emission or kinematics have appealing possibilities as they can effect constellations over time and suggest kinetic solutions for optimised thermal comfort in allowing sunlight to penetrate the envelope according to desired solar gain. This i.e. gently designed by Jean Nouvel in the Institut du Monde Arabe [Lepri, 2001] (probably not via motion software). But in order to construct a form, which can perform, the use of physical movement evaporates the idea of the dynamic parameters in static functional form and contributes to energy consumption through a great number of mechanical operations included in the building. Associative/ parametric formations has opposing potentials to improve the performative concepts due to form development with imbedded generative data, such as solar path of wind movements influencing the building.

Iterative progression

Creativity is in the nature of the designer [Lawson 2006]. In this perspective a complete computational cycle towards optimisation is an inadequate solution in solving environmental downfalls when striving towards performing buildings not only fulfilling quantifiable dimensions. A self-generating system described in the performance based generation models is thereby unwished with respect to the intellect and potential of the individual designer. Creating form via generative methods in iterative steps can however improve both performance and aesthetics due to parametric control and envision solutions unimagined to the designer for further development, being simulation analysis, material choice or modifications in spatial compositions et al.

Changing point of departure

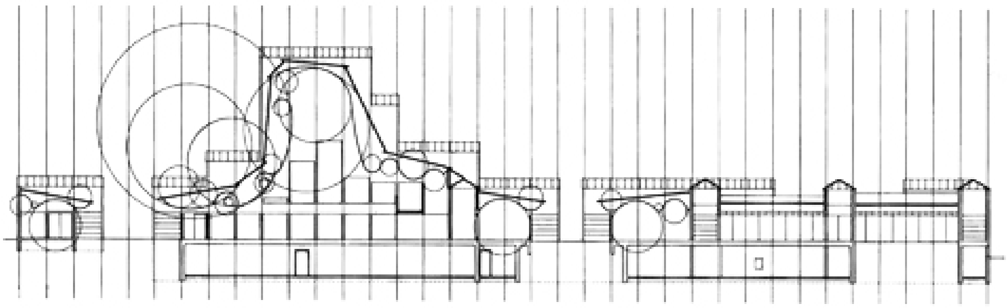
What is of significant interest in the other type of performance models - performance based formation models - are the row of order in which form is developed. Form is essentially created through variable parameters frozen in optimum constellations, which rephrase the way sustainable design is developed from prior Euclidian shapes of modernism. Thermal and light simulations would in this case show results far closer to wanted performance criteria's than if a random design was developed without knowledge of sustainable principles implanted in a conceptual design model.

Instead of being used in a passive, after-the-fact fashion, i.e. after the building form has been articulated, as is currently the case, analytical computation could be used to actively shape the buildings in a dynamic fashion, in a way similar to how animation software is used in contemporary architecture. [Kolarevic, 2005:p26]

A digital platform for conceptual design phases, with above criteria to an environmental performing form, can then be suggested in Performance Based Formation Models, with the use of associative/parametric modelling environments.

Approaching design with induced sustainable principles in the birth of form concept offers a new and more radical form finding process seeking to attack the problem rather than patching a former ideology. To enable conditions upon which the approach can be developed, a deeper understanding of the elements constructing the design progression are elucidated. The following chapter thus seek to frame a process path and ways of creative thinking to which above digital definitions are made possible.

Ill. 012 *Jørn Utzon*
Bagsværd Kirke



Utzon creates through the inner shell structure of the church a merge of acoustical, daylight, structural and metaphorical elements into one performing form.

Although sustainable parameters 'only' are present through improved daylight conditions, it reveals the possibility of a multiplicity of vectors, which just as well could be informed by sustainable parameters.

2.0 PROCESSING

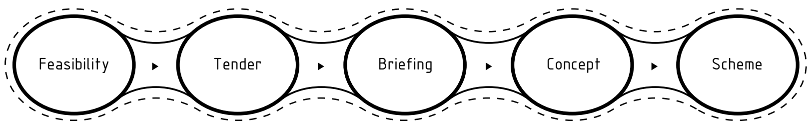
From defining a conceptual digital model in the last chapter to advance from, the following chapter will go deeper into the digital process parameters and constellations. A successive path through the 'processing chapters' is stretching from overall (2.0) process schemes, framing (2.1) creative cognition, advanced by (2.2) intuition and logic with the use of (2.3) explicit knowledge and concepts of (2.4) interleaving in architecture. Extracted definitions, concepts and relations from others and the work presented here finally suggest a progression scheme seen to frame methods for computational sustainable architecture. To re-surface into architectural praxis (2.5) cases are analysed to evaluate theoretical definitions derived by this work and to identify important sustainable factors and methods for later implementation.

Traditional processes of architecture can to a large extent be seen as a linear movement towards a final design suggestion [Szalapaj, 2005:p.120]. It includes often a series of design attempts with a varying number of influencing factors, depending on the capacity of the designer to introduce knowledge within and outside the architectural domain. The above illustrated examples all draw experience, techniques and knowledge from other fields than traditional architectural operations to progress via the digital medium and by that also introducing a new approach to conceptual development of form not only in content, but also in the shaping process. Even though many form ingredients are the same: compositions, materials, hierarchy, light, colours, geometry etc. a difference between analogue developed and digital generated structures are significant in handling of complex relations and their organisation from conceptual phases to construction [Kolarevic, 2005]. A shift as earlier mentioned has evolved recently from singular design formative entities to multiple independent and related parameters forcing integrated processes[9] to enable solutions.

Opposing schemes

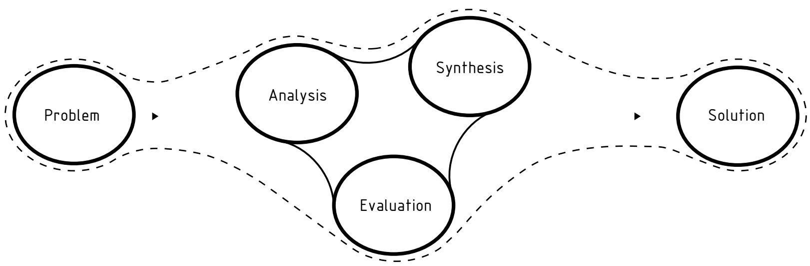
The design process itself is a very fragile substance to define in architectural practice, despite institutions equiping architects with methods and schemes of different phases of development, dissecting the process into definable periods in which predetermined actions should be done. For instance concept to design and design to detail is considered fluid for most involved in creative processes and perhaps even more for the exploring individuals researching in unknown terrain, which is evidently the case as showed with parametric models, shape grammar and evolutionary models. RIBA (Royal Institute of British Architects) is a renowned organisation with years of experience in architectural practice. They have formulated a scheme upon which architect's should/could progress their design (ill. xx) [Szalapaj, 2005:p.121]. Linearity is clearly the case in this image of a project development suggesting a clear step-by-step progress towards a solution to a defined building programme. Another scheme by the architect and psychologist Bryan Lawson (ill. 014) seek to introduce a more random organisation of process parts. A problem is defined and a solution must be reached via an undefined path through analysis, synthesis and evaluation. No hierarchy is defined to when parts are to be taken into use.

Ill. 013 *RIBA design scheme [Szalapaj, 2005:p.121]*
Linear process



The scheme illustrates a linear progression throughout the process, with focus to finishing one phase before entering the next, creating a rigid design environment, which poses the risk of locking a design process through its linear path.

Ill. 014 *Lawson design scheme [Lawson, 2006:p.49]*
Integrated process



The open structured model offers a frame for integrated design solutions through its centre phase, creating a base for interchange of different elements. The process becomes a constant evaluation of solutions to create synthesis in iterations.

By doing so, the controlled process is temporarily dismantled. For many this will be an unstructured, fluctuant and frustrating modus operandi with a large amount of variable elements to control simultaneously. Creative processes are often, despite the effort to control them via schemes like the one from RIBA, of unstructured character especially when referring to inexperienced designers [Lawson, 2006].

'Suitable scheme'

For the creation of sustainable design via performance based models operations a process scheme of open disposition must be chosen/created to support a design that is subject to alteration from many miscellaneous perspectives. The scheme designed by Lawson offer a frame for this development, but neglects to differentiate between analogue and digital process thinking within the suggested model. As digital media only slowly infiltrates the architectural practice instead of completely reinventing our way of working, a clear difference in working method and cognition may seem difficult to identify. However this be the case, essential significance can be explicated to illuminate a path towards conceptual design methodologies for new and improved sustainable solutions.

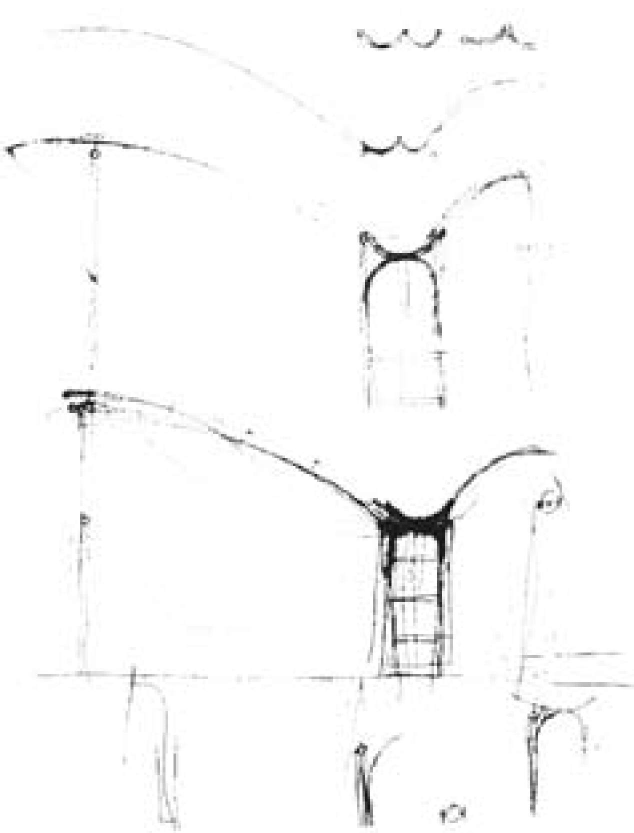
2.1 Creative cognition

Designing is a creative process, hence the use of thinking and use of knowledge, cognition, is indispensable to detect potentials of digital design progression. Undoubtedly the use of computers in the development of architectural projects is indisputable, through the use of drafting, modelling and presenting design schemes. What is of interest to this project is nevertheless the shift in the use of the digital medium from a post design tool, to an important factor in the development of the conceptual design, which prior was conducted solely by the imagination of the designer in analogue environments – sketching, collages and physical modelling among others. The way in which creative thinking is developing is so to say changing by the tools that we use as they are understood and interpreted for further progressing design in new directions. By tradition, architects were and still are sketching conceptual ideas on paper to communicate to others, but even more so to understand a thought of idea for further development [Szapalaj, 2005:p.211]. The sketch becomes a clarification of the abstract thought of spatial concepts, constellation or compositions. It thus becomes a translator for the designer to understand his/her own ideas. The same process of cognition in other analogue representations as physical models applies to the understanding of architectural ideas.

Digital

When developing/generating design concepts through digital medias, an understanding of the process that drives the design is fundamental as the input factors are evidently different to the ones of analogue processes. The coorporation with the computer naturally enforce a necessity to clarify the conditions upon which the design must be developed. This means, that

Ill. 015 *Conceptual sketch by Glenn Mercutt*



The drawing illustrates the process of articulating the roof for Mercutt's famous Magney House shaping the wished curvature and the meeting of the two roof sides. In the forming, he too optimised the performance of the envelope by adjusting angles according to solar paths.

knowledge of building parameters must be induced in early design phases as to develop form via preset conditions, being for instance of structural, environmental, social or constructional nature. In respect to sustainable design solutions, a clear understanding of parameters possible to feed the digital design engine must be considered, described and formulated in pre-design phases – such as solar paths, wind directions, geographical data etc.

Looking at theory of design processes investigated by Lawson [Lawson 2006:p. 41-44] in his experiments with scientists and architects given the same task to be solved a differentiation in problem-solving scenarios elucidate the cognitive approach. In the experiment the scientists seek to solve the problem first and then solve the task, whereas the architects solve the problem and task simultaneously – which leads to the conclusion of scientist having a problem-focused-strategy in nature and architects having a solution-focused-strategy. The search of logic and understanding to further develop ideas is thereby an approach adopted by scientific thinking. Digital form development can in this perspective then be seen as a scientific process of development as understanding and construction of predetermined definitions must be achieved to operate through digital tools with the aim of performative design. A wide range of knowledge that must be accessible to the designer prior to even starting a digital form-finding process is thereby of important impact. A new cognitive approach to design evolution is thus needed when seeking performance optimised architectural solutions by the potentials of the computer.

The change in creative cognition can then be compared to the threshold prior described from the classifications by Oxman between CAD models and the following models. Change in both methodological models and creative cognition is defined by the move from computerisation to computation, to which new understandings of design development must be acknowledged and in best case used for exploration. Implications to the way form is derived can be registered in the way we think before, during and after the design process as described through the experiment with architects and scientists. The creative process may in this case lie even before the 'normal defined' creative conceptual process, as ideas to solutions must be constructed to solve the greater problem at hand. To do so, logic and rational thinking, more affiliated with the work of engineers can be the path of manoeuvre for architects seeking to form performance.

2.2 Intuition and logic

Terminological contradictions frame briefly the definitions of the architect and the engineer to suggest the lines of thought in a joint venture. Training and working with very opposing vocabulary and methodological approaches to design inflicts problems in collaborations. Digital cognition and digital form generating environments induces possibilities for advancing these problems to reach a process where both have possibilities to advance design solutions, contradicting to well-known scenarios from the present state of the AEC (architectural/engineering/contracting) industry[10].

Working environments

One way of obtaining the above-mentioned criteria, intuition and logic, to improve the foundation of processes that enhance design solutions is to work in a combination of intuitive and logically digital environments. Conventional architectural applications have not managed to fulfil the requirements to such endeavours, on the contrary. The 'toolbox' can be divided into two categories; low semantic and higher semantic[11] approaches to digital forming [Aish, 2005:p.245]. These rather abstract notions cover working environments with lines, arcs and circles for the former and solids for the latter. While the first enables complete freedom to the designer, it also neglect to frame meaning. Opposing are solid predefinitions as doors, windows, walls etc., which indeed speed up process, as they simply are dropped into the 3-dimensional building, but also dissolve the possibilities for innovative solutions. Contradicting, similar to above described terminology, are engineering applications, which are controlled entirely by quantities, equations and graphs for explicit interpretation. Despite the technological impact several years ago with the development of profound software for optimisation and adventure in architecture, it is not until now applications support the intuitive and logical 'creative' working together. A series of new software packages support the suggested development towards performance design by offering new facilities for design languages to evolve.

Although designers are working graphically, based on intuition and experience in architectural design, the work is being captured in logical form, in what is effectively a program.

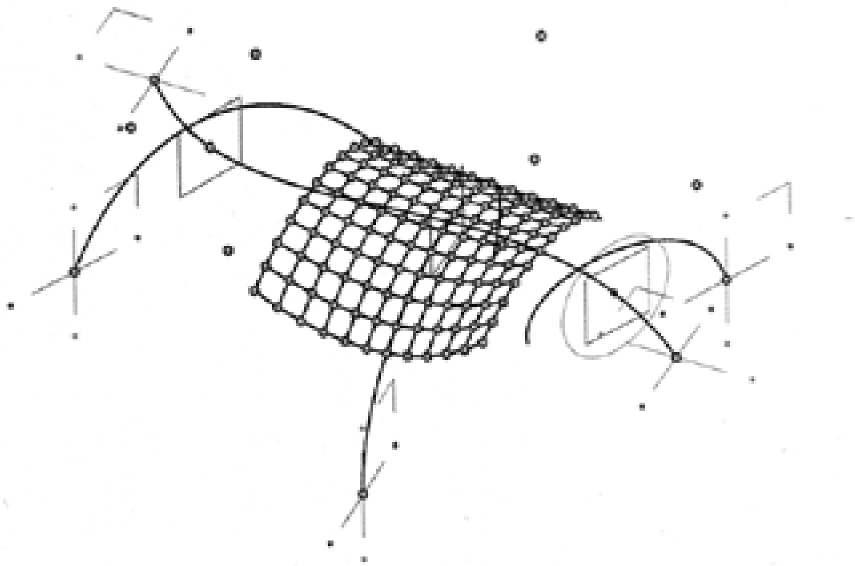
[Aish, 2007:p.2]

Logic is applied when relations of the greater system are created, as hierarchy, geometry and mechanisms all relate to the same conception. Parts become through the associations inseparable not only in thought, but also in managing. Both spheres (thinking and doing) are essential to understand and operate intuitively in a systemised conceptual design environment. It is the task of the designer to manage this complex mission to achieve an improved result and not solely depend on the development of new software to solve intricate architectural problems.

Despite the field is moving towards improved conditions for constructing design based on performance criteria, in which some applications even are capable of generating form from data, as described in performance based generation models, a difference in thought must be obtained.

In doing so the architect must master two and quite different ways of thinking. To return back to notions of creative cognition, autistic thinking[12] and reasoning[13] [Lawson, 2006:p.137] are perhaps illustrative psychological terms to understand the difference in thought when

Ill. 016 *Geometrical model of double curved surface*



The geometry model illustrates control points, curving splines and a populated point grid. Everything changes according to the movement of one of the entities.

discussing a combination of intuition and logic. Autistic being normally related to creative thoughts and reasoning being directed towards a given conclusion.

This implies yet another level of change in a domain dominated by subjective, implicit argumentations and descriptions. Argumentation above suggests provoking creative processes even before they start through digital cognition and with the following concepts introducing another and compatible source – the use of explicit terms to facilitate such an approach.

2.3 Explicit knowledge

The importance of the technological development within architecture is, as mentioned earlier, being manifested in both solutions and processes. Enlarged injection of data into all phases differentiates the prior processes from the contemporary through their relation to explicit knowledge instead of earlier implicit statements. Explicit formulation is a continuation of the logic implementation into architecture as progress operations are clarified by definitions in absolute expressions.

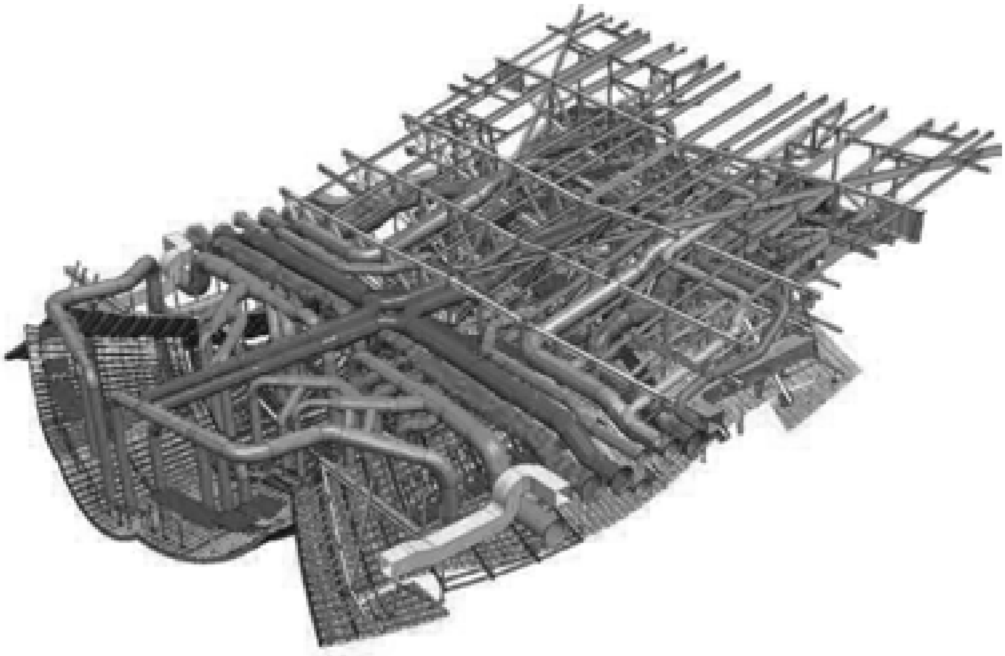
In a computational view of design the explication of cognitive processes is based on our ability to formulate, represent, implement and interact with explicit, well-formulated representations of knowledge. [Oxman 2006:p 243]

This radically changes the basis upon which design is communicated between various project members, external partners and client. Measurable dimensions are now becoming increasingly traceable through the process for more clear judgements on various design solutions constructed. Clear definitions of design concepts eliminate in this way the architects position as independent design entity as he/she no longer is the only one to interpret the design/sketch, being and open-ended information model of quantifiable solutions visible to all members of the design team. Subsequently is architectural form derived from information.

Explicit modelling

Responding to above described complexity, creative thinking, use of explicit terminology and information modelling new holistic virtual environments are created, named BIM (Building Information Modelling). Gathering of information into one explicit model including analytical tools, material properties, visual output in the form of online display or drafting possibilities and construction information by timeline enables complete and precise assessment of cost analysis, performance analysis and maintenance requirements throughout the lifetime of the building. Explicit knowledge is covering all aspects of a building progression to clarify problems and opportunities for the design team.

Ill. 017 *BIM model from Gehry Technologies*



Gehry Technologies' BIM software frame the complete organisation of a building, including 'hidden' elements as ventilation ducts, structural members et al, in 4-dimensional descriptions. Thus informing contratctor when and how to build what for a fluid construction process. Further information about maintenance ensures life-cost analysis and warning systems to when parts require inspection or replacement.

Comparing the process parts: simulation, evaluation and synthesis defined at page 34. with the working method presented here through Building Information Modelling software and effective performance based formation models, elucidate similarities in progression hierarchy via constant interaction between the different parts. Developing form in explicit environments, even in conceptual phases through defined relations in parametric models, then seem to offer a more loose defined process from problem to solution as advocated although being of more controlled character. Freedom and creativity thus return despite introduction of explicit methods in architecture.

Operational languages

For intuition and logic by explicit knowledge to work an extension of the vocabulary foundation in architecture is necessary. The creative process via digital design tools has indorsed new operational languages to obtain fluidity between generating tools. Departure from low semantics and higher semantics into parametric and mathematical notations are evolving along the recognised opportunities and power framed in computation. Manifest of explicit descriptions in performative architecture can simply be viewed by the way complex buildings are designed and shared in programmatic environments entering new perceptions of spatial understating, prior understood via sketching and other analogue representations. Flow of spatial, geometric and performative information is compressed into its pure components and shared in collective design spheres provided by various scales of networking facilities, from offices to global connections via the Internet [Silver, 2006]. Emergent technologies and techniques are by these channels developed as a collective intelligence [Height, 2006] enabling abstract and concrete architectural solutions far beyond prior means of collaboration and integration of influencing elements towards form. The language is open and shared in societies of artists, engineers, programmers, mathematicians and architects.

Universal language

Mies van der Rohe, famously described modernism as the universal language of architecture [source]. Without commenting further on the postulation, besides questioning the depth of the statement viewing the impact on the present ecological balance, a more appropriate content for the term universal language could be the language enabled by coding/scripting to context. This does not imply any particular visual style of architecture, aiming instead at the process language from which architecture evidently is a derivation of. Coding offers a new universal instrument for open-ended solutions in architecture, much different to the universal language that the modernists proclaimed.

Architects are all too often delivering a design solution dictated by a house style, which the client is buying into as if it is of the peg regardless of context or use; if they are purchasing a Gehry building, they require it to have all the signature flourishes and forms. The paradox of 'signature style' does not address the complexities of contemporary living. (...) It is natural, therefore to explore radical alternatives, to invent and develop new creative methodologies. [O'Carroll, 2006.p:102+]

Ill. 018 *Script from Generative Components*

```
transaction modelBased "Prepare to generate feature type GC.pop01"
{
    feature bsplineSurface03 GC.BSplineSurface
    {
        Curves                    = {bsplineCurve07,bsplineCurve08,bsplineCurve09};
    }
    feature openFac GC.GraphVariable
    {
        Value                     = 20;
        RangeStepSize             = 0.0;
    }
    feature point29 GC.Point
    {
        DistanceFromOrigin        = Distance(point32,coordinateSystem01)/openFac;
    }
    feature point32 GC.Point
    {
        CoordinateSystem          = baseCS;
        XTranslation              = <free> (-0.864090546890717);
        YTranslation              = <free> (-1.26674141667788);
        ZTranslation              = <free> (0.301621127089007);
        HandlesVisible            = true;
    }
}
```

A small part of the script developed in 'Generative Components' generating variable parameters to optimise the geometry of the surface. This ensures rapid alteration possibilities for the designer after simulation feedback. The script is open-ended and can be re-written by any involving member of a composed design team.

The outcome of the script can be viewed in experiment 1, page 92.

Explicit steps

Although extension of computation into architecture offers a series of explicit advances, it will hardly fulfil the gap towards performance driven architecture with the intention of improved architecture in a holistic image. It is widely recognised that diversity, individual creativity and reasoning generate novel concepts of simplistic and complex nature relating from contextual elements to human behaviours. By constructing a dialogue of iterations between computational and personal steps, a methodological foundation is developed enhancing opportunities in collective progression, performance and diverse visual languages. Ironically explicit knowledge contributes to greater freedom in architectural exploration and enables new levels of interleaved processes to accommodate the scope of this work.

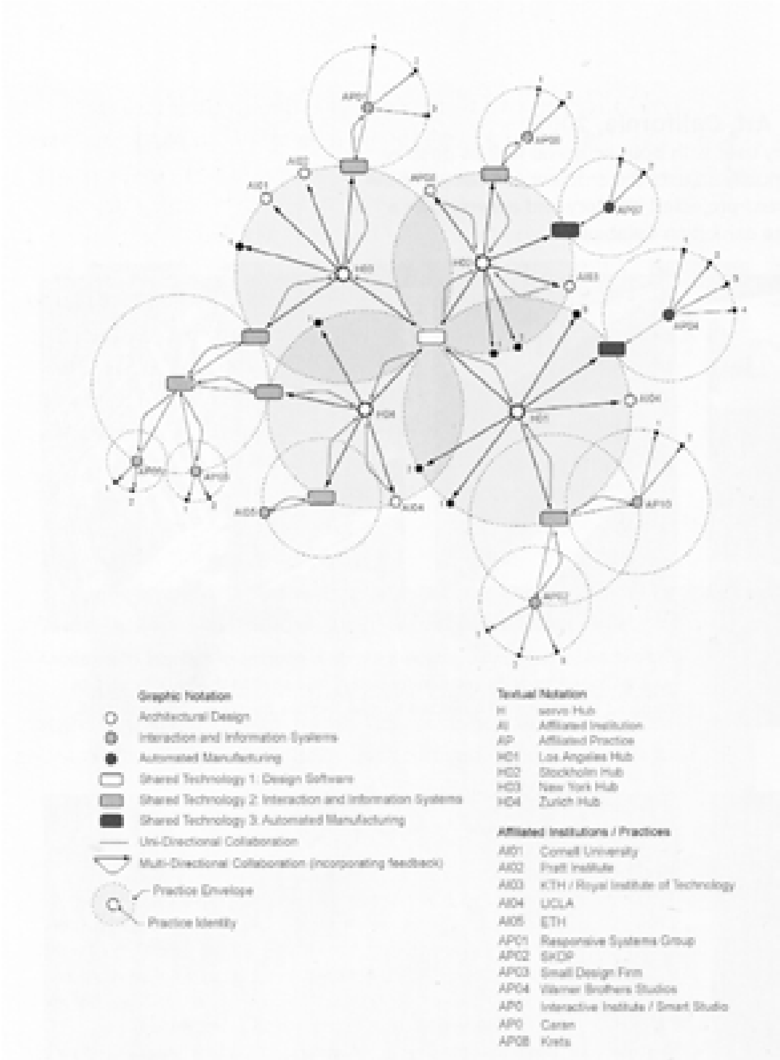
2.4 Interleaving

Towards a process scheme a theoretical 'spine' must be formulated to locate the former described explicit steps and to ensure freedom during the creative process. Sequential row operations can then be exchanged with interleaved processing, enabling the designer to move forward despite changing parameters implied in earlier form evolution. Interleaving means briefly to place something between the layers (of something). By doing so a non-hierarchic design model is constructed making it possible to transform the design in various scales in various times.

Placing something can naturally be of different character. It does not necessarily mean that new architectural elements, such as walls or doors are exchanged or moved. The term in this case refers to placing new informational elements; such as descriptions of solar gains in different zones, desired lux levels or temperature gradients in the design model to compositional relations. This provokes progression, optimises performance and by that alters visual appearance, dominated by logic and intuition in an undetermined visual language. Computational interleaving thus becomes a process where designer and computer proceed solutions together and enable a multiplicity of acting members with thought to supporting several designers and computational operations.

The speed and access offered by information technology can shrink the lag between the conception of an idea by one participant and its communication to other participants for the purpose of review, comment, or as a springboard for new ideas. Thus, although information technology is merely a technical, quantitative measure, it has qualitative implications as well: it can support, or at least accommodate, the uniqueness and unpredictability of creative design processes. [Kalay 2006 p.362]

Ill. 019 *Collective Intelligence*



Joint communities of private architectural practices and experimental schools of architecture are mapped in a diagramme to illustrate the collaboration enabled by open-ended scripted architectural models in open communication channels, such as the Internet. Operation across the network offers endless constellations of specialised project members from various disciplines.

Grouping

As interleaving indicates, input of divergent content is favoured, opening locked collaborations between members of the design team. Classical architectural terms and engineering notions construct simultaneously the design model in a continuum of alterations, quantifiable and qualitative evaluated in simulation software and physical models via rapid-prototyping[14]. Dialogue through computational technology and well-constructed process schemes bridging disciplines becomes of opportunistic dimensions to the performance driven creative process [Kalay, 2006:p.364]. The conceptual design process can in such ways through interleaving enable not only several design partners, but also their input on several operational levels simultaneously, as a way to progress faster and to illustrate or simulate solution scenarios in a holistic concept, rather than an idea developed from a single perspective.

Operational levels

When seeking solution to a problem, most architectural designers choose a scale of departure. This implicates a bottom-up (starting with detail or parts of a building) or top-town (starting with the overall shape of the building) approach to which form derives from. The building style of each approach is often visible through the rather different initial ideas in the creative process. Working trough interleaved processes enables operation on all scales simultaneously, improving design members' freedom and their individual contribution. Tectonic definitions in architecture manifest the importance of the joint – the detail [Frampton, 1996] while contemporary building complexity require organisation of intricate spatial organisations and a desire to construct an attractive building envelope. A vast amount of perspectives on architectural scales are then merged into a concept in which they are related to each other supporting multi-induced information models, in relation to scales and profession.

Extracting process

In clarifying of the last processing chapters and the successive row of definitions stated, an outline of process parameters is defined for continuing development towards a set of procedures constructing a framework. The interleaved process model suggested builds upon the following parts:

a) Open-interrelated structure based on Lawson's process model.

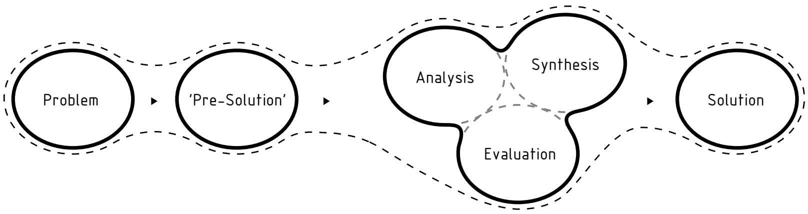
b) The use of scientific cognition based on digital form finding.

c) Logic implementation to construct improved models.

d) Explicit definitions to enable operations across disciplines

The idea of the model is not to define a way to construct a set path towards sustainable performance solutions but to create a foundation upon which an infinite series of possibilities can be developed according to the talent of the designer/design team by informing a computational model and to interact with it. Not unsurprisingly is the formulated model similar to the one defined by Lawson, as they both seek to frame optimum freedom in creative processes. The main difference lies with the solution-focused-strategy due to digital cognitive processes and with the explicit implementation into analysis, evaluation and synthesis, which is seen to dissolve the distance between the three parts significantly towards a solution from the earliest phases of designing.

Ill. 020 *Computational design scheme*
Solution searched from problem



The resulting scheme is incorporating a phase dedicated to pre-solution constructs, responding to digital cognition and computation. This has then effect on the following phase to which analysis, synthesis and evaluation is linked closer to each other.

2.5 Case

To relate the formulated computational process scheme and to extract sustainable ideas in digital influenced projects, a small series of cases are studied. It is a method to analyse qualitative examples to verify concepts developed by this work and to constitute theory into praxis. The examined projects are subsequently used to improve and/or support the scheme suggested. As prior mentioned is the field of digital architecture expanding rapidly, though without an equal implementation of digital projects into the physical world. This, combined with a search for sustainable implementation narrows the field of investigation further. The presented projects are at present as such alone within this search, which then qualify them for analysis. Each of the projects is evaluated through the same evaluation points.

[A] *London City Hall*
Architect: Foster+Partners with Arup

[1] Implementation of solar energy
The overall building form of the city hall is developed partially from the path of the sun to minimise southern sunlight by leaning its body in a self-shading angle. In doing so, solar gain is reduced in the global building shape. Solar simulations detail this pre-design approach by localising energy gains through the window placements to categories overheating dangers and glare control. A change in appearance from the competition design to building design, is done via this analysis, changing the northern glass area (the eye) into a pine-cone shape to avoid the above mentioned problems. Each window partition is in this way simulated for optimum daylight and solar absorption.

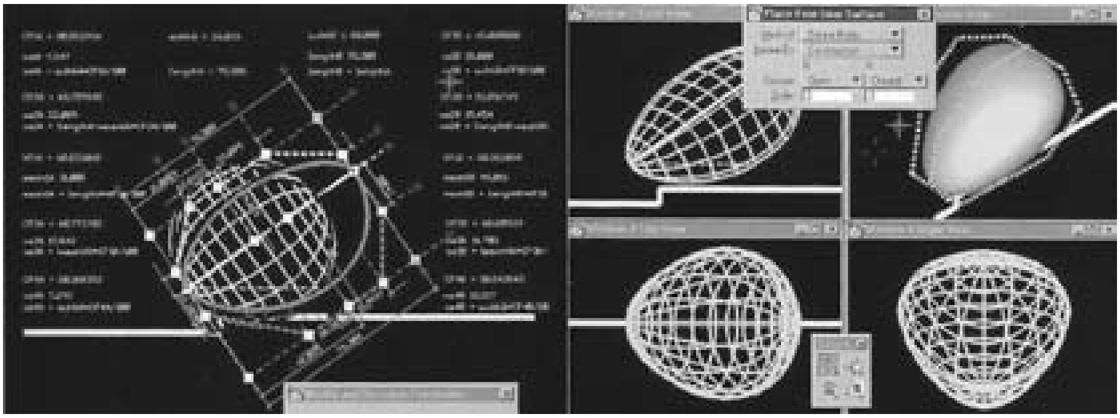
[2] Use of wind
The City Hall is equipped with mechanic openings in the façade to adjust ventilation requirements. Natural ventilation principles have however not been a constructive parameter in the development of the form.

[3] Spatial organisation
Offices embrace the centre hall and become thereby a buffer between southern exposed facades and the most important space in the building. Smaller spaces (offices) which are easier to control thermally are in this way sheltering the council hall, which is a large, complex spatial geometry with needs of precise control in humidity and temperature.

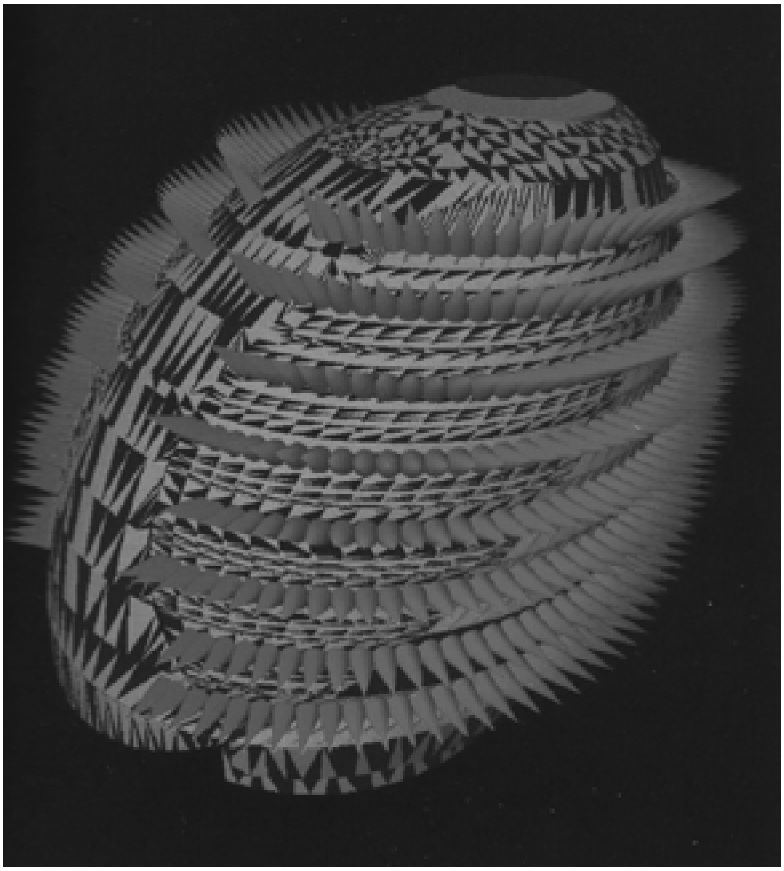
[4] Material interventions
Concrete, steel and glass are evidently the constructing the materials chosen. By tradition and performance, Foster and Partners favour these materials. Little if any intervention in material use is seen used.

[5] Level of computation
A distinct incorporation of computation was achieved by extensive pre-modelling work to construct a geometric model of associative character to enable designers 'free form' exploration in connection to the set constraints set by proportion ratios. Geometrical visual was developed via 'trial-error' handling to find the optimum shape, which later informed the entire

Ill. 021
Associative model



Ill. 022
Exposure simulation on window panels



construction process. Solid models were constructed via rapid-prototyping to visually analyse concepts and solutions. Panelisation et al was then drawn directly on the solid model linked to registration software, reading the pattern constructed on the solid model, directly implemented to the digital model. Extensive thermal and acoustic analysis was conducted to inform changes in the associative model. This was handled manually and not as digital respond from simulations.

[6] Level of cross-disciplinary designers
The project was developed from a series of units, gathering a multi-professional team, a design team, geometry team (SMG -), model team and ARUP, working as external partners. Information of geometry, performance and expression was shared between the different units via spreadsheet documents. A large number of experiments/iterations were in this way possible and offered several perspectives on improvements – from performance requests to aesthetics.

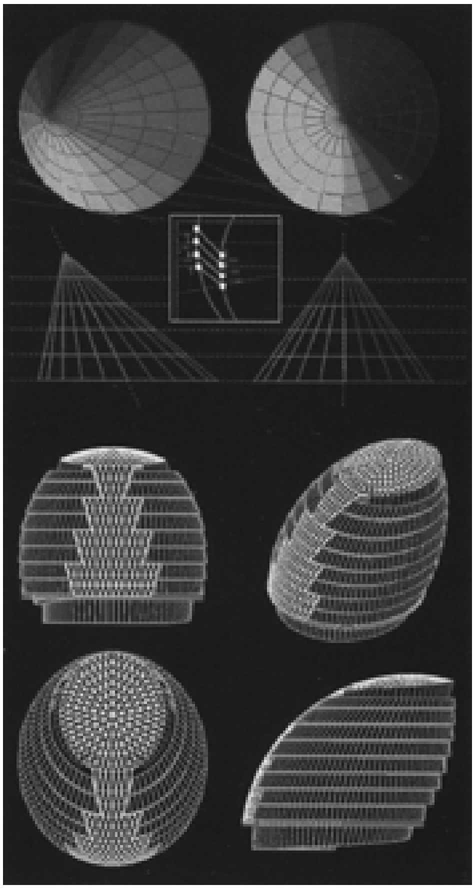
[7] Phase constellation
Despite extensive use of computation a pure analogue design was created arbitrary [Kolarevic, 2005:p. 85] and then recognised to be an ideal form for further improvements. A parametric model was constructed to alter proportional relations in rapid modes leading to an informed model of assembly possibilities via different panelisation methods, exploited within the parametric model. A series of analytical iterations altered the inclination angle and the inner pathway surrounding the hall. The digital model was finally used in precise descriptions of material dimensions, tolerances, behaviours and assembly.

[8] Summary / Evaluation
Through computation an extensive array of iterations are done from analogue to digital and performance to visual expression. Various disciplines inflict on the performance and looks of the building, which alters the shape more in detail than in building-body. Surprisingly is the building through those iterations changing very little in appearance and indicates a large knowledge of sustainable indicators or a strong desire to keep a pre-chosen formal language. An indication of performance driven architecture is though visible in the noticeable difference of the lens towards the waterfront as a respond to solar exposure.

When comparing to the formulated computational design scheme many similarities in process and methods can be recognised. A pre-solution is designed and directly altered via analysis, evaluation and synthesis, which are closely joint to construct performance based solutions. To fit the scheme more precisely a solution not dominant to the rest of the process should have been developed, instead of a model seen to control further operations. The minimum change from conceptual idea (competition entry) to building can be caused by the strong aesthetic shape, which is either kept and improved within the boundaries of the design or rational altered to accommodate other constraints. A top-town approach towards the final appearance can be registered in the work of many renowned architects.

Ill. 024
Finished project by the River Thames

Ill. 023
Geometrical relations describing the building



[B] *30th Saint Mary Axe*
Architect: Foster+Partners

[1] Implementation of solar energy
Sunlight enters the building through the glass coated façade and through the six 'courtyards', constructed by cutting a triangular shapes of the plan organisation through the entire building. By rotating each level a spiralling effect occurs, functioning as internal voids. The gained daylight lowers the energy consumption with fifty percent, compared to similar buildings.

[2] Use of wind
Natural ventilation contributes heavily to the reduction of energy by its vertical spiralling shafts in lowering air-conditioning needs. Due to the circular shape and spiralling atria is the natural ventilation system functioning in lateral wind conditions via several openings. In summer, cooled air enters offices, while in winter periods heated air is delivered due to the voids functioning as a double-layered building skin.

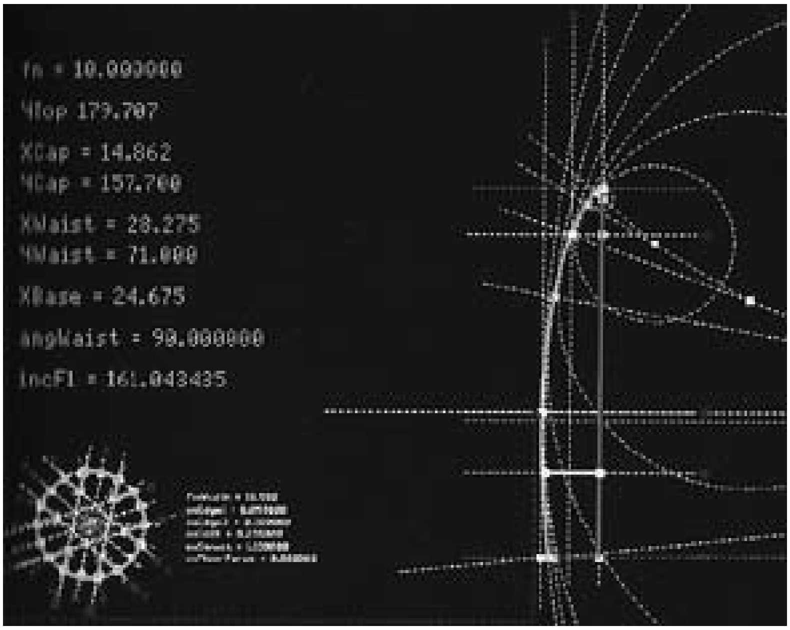
[3] Spatial organisation
The floors are divided into six units due to the separating atria, in open organisation. Free movement is thus offered to employees with short distance to a void offering fresh air, visual contact to above and below floor and view over London.

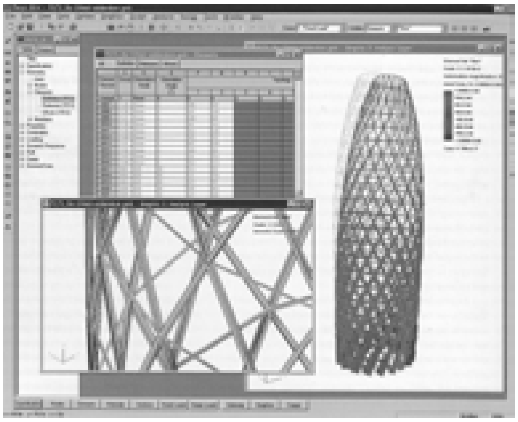
[4] Material interventions
As with London City Hall, Foster chose to work primarily with steel, glass and concrete with known structural behaviour.

[5] Level of computation
Similar computational constructs to the ones of the City Hall are developed to optimise form and process. A parametric model is developed to rapidly iterate proportional ratios in plan and section. Building profile is via the associative model altered with few handling points to relate building shape to adjacent urban fabric and simulation software. Structural behaviours are analysed via spreadsheet environments, visualised in point clouds. The entire main geometry is computed to improve performance.

[6] Level of cross-disciplinary designers
A long series of partners have developed the building along with the design team from Foster to create the simple overall geometry. The explicit expressions are by data shared to give visual output and performance overview enabling cross-reference analysis, as to enable solutions for both structural and environmental issues. The key element of the cross-disciplinary teamwork can be monitored in the spiralling composition in which optimum structural organisation is reached with a solution improving daylight and natural ventilation.

Ill. 025 *Relational behaviour respon in plan and section*





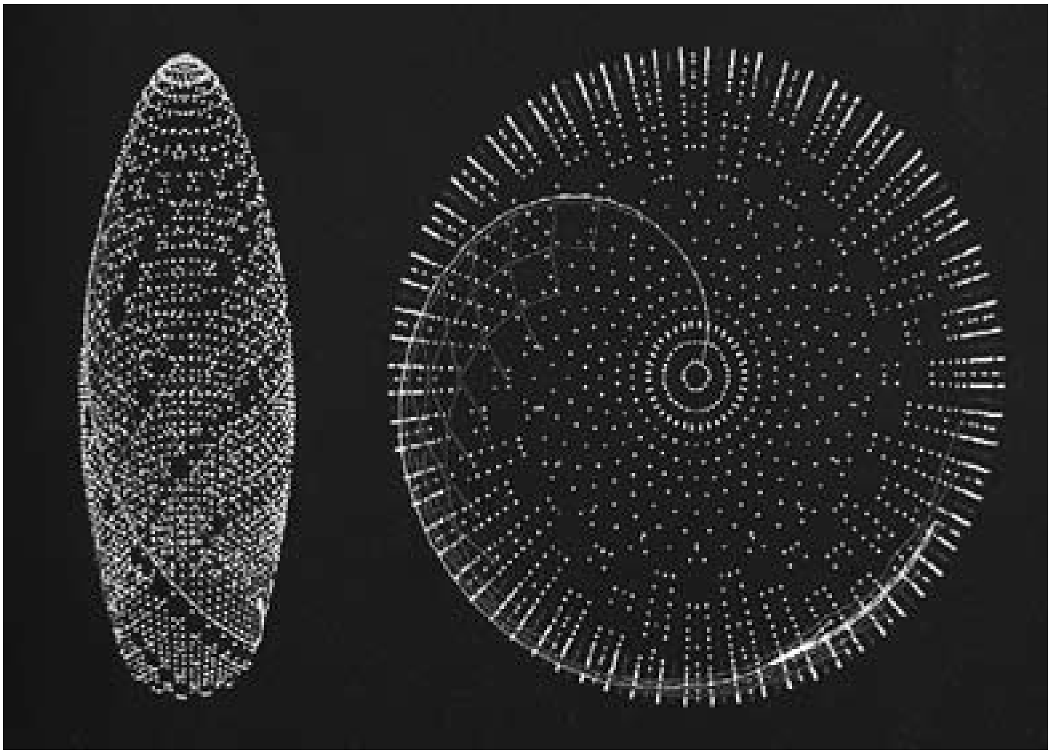
Ill. 026
Modelling data shared via excel sheets

[7] Phase constellation
Many different conceptual designs were sketched in analogue environments before starting an actual form finding process. Following this process towards a conceptual form, computational models described above were created. Iterations optimising profile for performance and constructional parameters such as triangulation of material plates et al was of priority towards the final scheme finished in 2004.

[8] Summary/Evaluation
Managing a complex structure and spatial programme and re-model the outlook many times faster than prior is shown possible in the probably most successful implementation of computational power present. A simplistic shape is developed through the simple, but powerful Excel programme to maintain a minimum of complexity in file sharing and thereby a reduction in errors during the process via the many partners sharing of files. Significant levels of complex parameters are controlled in digital environments improving structural, environmental and spatial elements.

Despite the atria multi-functional features to be sustainable improvements, a complete glass covered building skin has by experience showed overheating temperatures during several months of the year, persisting air-conditioning systems to lower the energy consumption performance. Glass could with respect to the typology of being an office building, being replaced by other materials improving thermal conditions. Though material interventions are far from realised in the project, a strong architectonic composition is constructed, and has with improved aspects of environmental, structural, spatial and urban character envisioned possibilities in the creation of performing form in architecture.

Point cloud creating the parametric model
Ill. 027



Ill. 028
The office building in its context in London

[C] *Fulton Street Transit Center*
Architect: Grimshaw Architects + Partners

[1] Implementation of solar energy
Shell curvature and apex opening is designed to take use of natural daylight in the centre space. Control of seasonal solar paths and their corresponding effects inform the overall shape to optimise reflection into the remaining space.

[2] Use of wind
No data suggests an improved form finding process by implementation of ventilation strategies.

[3] Spatial organisation
The transit centre is through a simple layout constructed via a rectangular box and the centre shape, constructing an overall simple spatial organisation. Due to the large footprint of the box, compared to the centre shape, solar energy is not exposed to the bottom of the centre, which then only allows sun to enter through the apex opening, being designed through solar exposure concepts described above.

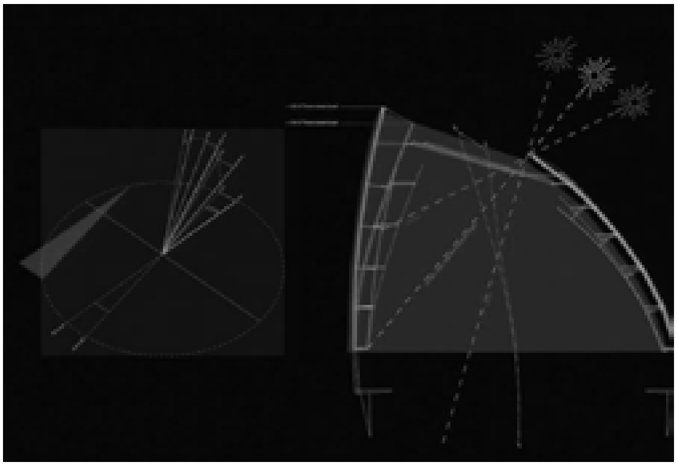
[4] Material interventions
Steel, glass and concrete are used as materials for load bearing construction and building skin as with the two prior cases from Foster + Partners.

[5] Level of computation
Overall geometry to structural members and façade panels are associative controlled according to parameters. The total of building elements are thus following the computation alterations informed by the designer (aesthetic wishes) and weather conditions (solar paths), which then are simulated for performance results.

[6] Level of cross-disciplinary designers
Due to the desire of sustainable-implemented elements, climate engineers and architects have created a corporation through a digital model, informed by explicit data from simulation and form perception of the visual defined architectural form. Construction and fabrication data are also incorporated into the model from which sub-contractors can be included in dialogue of cost analysis.

[7] Phase constellation
Though no data are available to classify a process path from, the idea of an adaptable form in perspectives of performance and aesthetics suggest a conceptual form sketched by the architect, to which alteration can be applied from diverse building disciplines (A/E/C professions) and subsequently improved through an integrated process towards construction.

Ill. 029 *Parametric/associative constructed centre geometry*
Fulton street transit centre

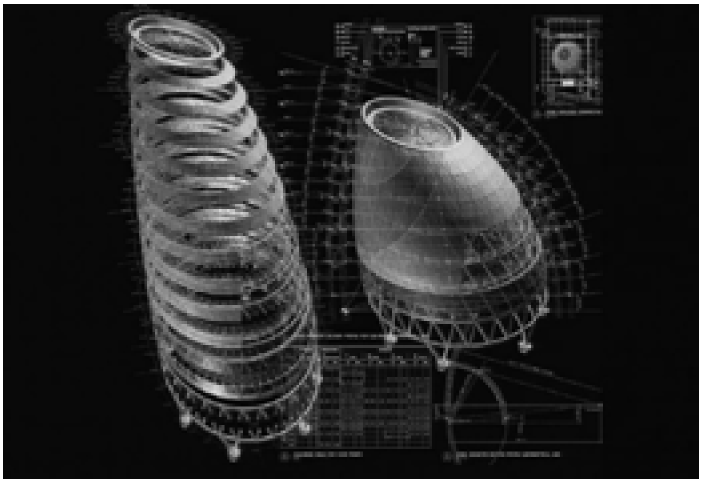


Ill. 030 *Environmental parameters*
Fulton street transit centre

[8] Summary/Evaluation
The somewhat simple architectural shape of the centre building and its interior programme consistent of only one large atrium space contradicts the two prior cases and illustrate possibilities of adapting a complete building volume according to sustainable concepts through computation. Alteration of form is thus moved from parts of the building (e.g. façade components) to the architectural body.

Despite integration of solar parameters to construct form, a high level of sustainable implementation is lacking through the absence of other sustainable factors, such as wind and material interventions. Merge of material tactility and engineering optimisation thus result in industrialised materials, far from sustainable in production.

Compared to the process scheme formulated, similarities can be identified to the concepts of creating a conceptual form, with embedded potentials of adaptability towards performance criteria's (pre-thought-solution). The concept of a simple geometrical constellation to evolve performance form from has potentials when constant evaluated from several sustainable factors, not only solar parameters as illustrated in this case. Adaptability must thus be applicable in both overall building topology as presented here, and component level as presented in London City Hall.



Assembly of parametric constuction logic
fulton street transit centre

Ill. 031

2.6 Processing conclusion

Though the extracted process at page 47 derives from theoretical definitions are resemblances to practical project observations highly present. Creative cognition towards performance based architectural design is therefore through the integration of both performance optimisation and visual exploration existent, though far from fully implemented. The projects by both Foster and Grimshaw neglect to incorporate adaptability in all design scales, which lock design alteration according to performance information. Initial design concepts thus continue, mostly unchanged despite of several design influencing parameters.

A fully conceptual performative process model offers thus operability to which visual expression and performance optimisation can be reached in an interleaved process following the pre-though-solution. This implies a model, which in thought and handling can be altered in both building and component scale, to which comprehensive form information and extended design concepts are needed.

Beyond investigation and formulation of process schemes lies a critique of a neglected curiosity towards material behaviour, performance and properties in the search of novel and topographical solutions. Steel, glass and concrete are to a large extent the only materials used, which provokes the question of an ignored sustainable approach is present? Focus is set towards technological expressions and believes in solutions through technical/industrial solutions.

In addition to theoretical defined parameters, which construct a process path, are elements recognised as present and missing in the case study of relevance in the construction of a framework for computational sustainable architecture.

a) Open-interrelated structure based on Lawson's process model.

b) The use of scientific cognition based on digital form finding.

c) Logic implementation to construct improved design models.

d) Explicit definitions to enable operations across disciplines.

e) More advanced and operational pre-solutions at all building scales

f) More freedom of change within the pre-solutions to create adaptability throughout the process

g) Emphasis on both geometrical systems and material systems

With the scope of a framework enabling both technologies, topographical and human parameters for computational sustainable architecture a more diverse approach than the one presented through the case examples must prevail. To inform the process scheme suggested and 'tested' with knowledge, different perspectives are illustrated to define the process model further and to suggest knowledge implementation through the merging of architectural domains in the following chapter.

3.0 MERGING

The Processing chapters showed implementation of new architectural process approaches to create form in creative digital design phases, to which knowledge perspectives, intuition and methods can be implanted. The continuum course is then to satiate the process with information of exact knowledge, methods and space for intuition. The following chapters illustrate and describe perspectives on sustainable architecture and computation used to process thoughts and techniques in joint relations of oppositions to maintain equilibrium of input. So far, merging of elements, knowledge and people have shown fruitful in analysed projects and theoretical definitions, and will in this work frame the following chapters: (3.1) Knowledge and Heuristics which elucidate necessary comprehension of knowledge levels and their use. (3.2) Technology and Art, discussions relating positivism and phenomenology to the researched subject. (3.3) Control and Chaos, discussing the roles of architect and the computer, to lastly formulating knowledge perspectives and levels necessary in realising the merge of computation and sustainable architecture.

Despite the Merging sections being related to each other through theme, they singularly seek to describe different argumentation and input towards computational sustainable architecture. They are as such parts of a whole. Extracted knowledge definitions are seen to locate essential perspectives on the researched subject to inform practitioners of the approach of thought necessary to execute computational sustainable processes and subsequently the derived design solutions.

3.1 Knowledge and heuristics

Feeding the process with knowledge is possible through different operations and accommodates different tasks equivalently. However, the term is commonly used without further definition, a clarification of knowledge levels might help to understand the operational complexity inherent in computational sustainable architecture and more importantly clarify when to apply scientific knowledge within the formulated process scheme. All processes are not necessarily induced by the same complexity level and are therefore additionally based on heuristic conceptions[15].

In order to approach a sustainable design, several contextual aspects must be understood and considered from mapping of forces to the effect of them (for instance). Simulation and evaluation are often used as procedural methods[16] and requires deep knowledge[17] [Shaviv et al, 1996:p.258]. The level of knowledge required can then be identified by the information amount and intricacy to comprehend the information.

Studying the output of the analytical computational operation can in many cases be as difficult as to inform the operation, which again refer to the importance of explicit knowledge prior described to advance with computation. To accommodate architects not trained in engineering or scientific disciplines, applications operating with simplified procedural methods have been developed, based on the same knowledge [Shaviv, 1996], which evidently brings back the problem of deep knowledge in sustainable design solutions. In a last simplification of procedural operations, heuristics can be used, based on prior experience, through similar tasks as the one at hand.

A line of knowledge levels can then be traced inverse of the three levels described above to support the computational scheme formulated at page 47 to enable a satisfying input of information into the conceptual form finding phases, without suffering from insufficient informed models and an overrated amount of data, disabling a fluid design flow in conceptual form finding phases.

Recognising the nature of the problem and responding with an appropriate design process seems to be one of the most important skills in design. [Lawson 2006:p.108]

Computation as with all other architectural processes is in need of knowledge implementation and use of heuristics in accurate constellations to advance, rather than conflict design questions. Recognising an appropriate design process is naturally evident as advocated and developed in prior chapters, but must also be packed with the correct perception of knowledge in each operation through the creation of design. Heuristics is in this case seen to prelude incorporation of deep knowledge.

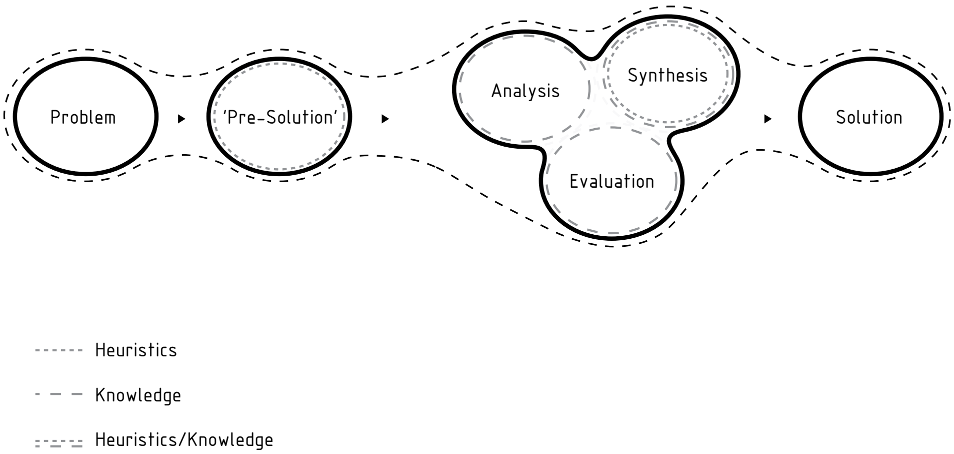
Towards detailing a computational sustainable methodology, heuristic and knowledge operations as terms can be applied to orientate what digital methods are suitable in the different parts of the scheme. 'Pre-Solution' is as described seen developed through heuristics to inform the model for proliferation and optimisation in Analysis and Evaluation, which is then primarily based on knowledge feed. Synthesis is seen to be a combination of heuristics and knowledge by the combination of experience on design issues and explicit knowledge (ill.033)

Knowledge levels are then helping to understand the inherent knowledge requirements of different phases, but not what type of knowledge is used. This will be investigated in the following through opposing spheres of thought.

3.2 Technology and art

In 3.1 Knowledge and Heuristics, levels of knowledge were applied to the work and formulated design scheme (ill. 033). This chapter approaches knowledge in the perspectives of theory of science defining spheres of knowledge instead of levels to endow an understanding influencing the architectural approach to sustainable architecture through computation. Architecture being parted and gathered in both technology and art through among others structure by

Ill. 033 *Knowledge and Heuristics applied*



Knowledge levels applied to formulated design scheme elucidating required levels of scientific input.

the laws of physics and the artistic perception of composition, hierarchy, colours and light, is subject to many perspectives of comprehension.

Implementation of computational performative methods is not seen to change this meeting, thus defined as a merge of paradigms in technology and art – logical and intuitional methods – represented in positivistic and phenomenological theory.

A brief introduction of the terminology identifies the differences and perspectives projected on the subject, followed by a technological part via positivistic approaches and perspectives in computational architecture. Subsequently is the artistic part discussed based on phenomenological understandings of sustainable architecture, to finally insert the philosophical perspectives into the theory of this work to give a wider portrayal of the researched theme in comparison to prior architectural discourse and to identify necessary lines of thought in computational sustainable architecture.

Phenomenology and Positivism

Analytical, rational and logical terms are descriptions of positivism presenting theories of 'pure science' [Delanty, Strydon 2003] through its objective analysis and understanding of the world, while phenomenology opposing is defined by subjective experiences of the phenomena in the world around us. In science, phenomenological and positivistic perspectives are in great contrast to each other but serve important aspects of fusion in the use of computational potentials, seen as highly technological, while sustainable building culture driven by artistic relations is appealing to descriptions of subjective experience.

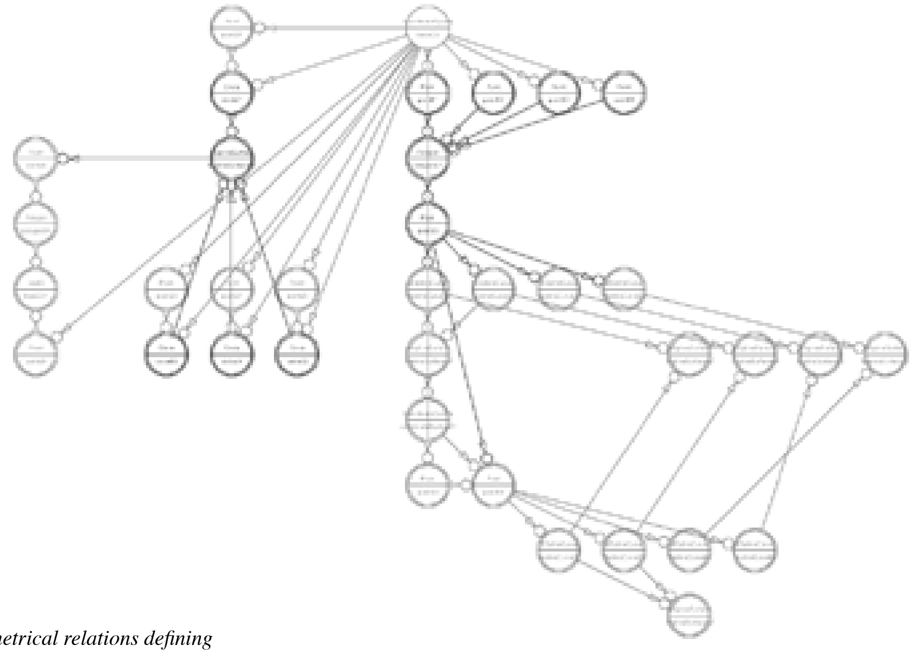
Technology

Both 'virtual' and physical technologies and techniques are in this work considered when referring to technology, mirrored in the exploration of software tools and material interventions in contemporary architecture. Today, technology derives from knowledge activated into systems and operations based on reality, relating to theory of the nature of reality – ontology [Delanty, Strydon 2003]. Indeed technology must be based on reality to be used in scientific work to qualify for valid experimentation and acceptance of the reached result in positivism.

Subjectively experienced qualities – redness, pleasure – are as such only experiences, not knowledge: physical optics admits only what is in principle understandable by a blind man too.
[Neurath, 1929, early positivism]

Architecture has with technological interventions through software development and its classical subjective nature a possibility to merge the two (positivism and phenomenology), despite the above citation strongly defies against it. But what can then be seen as positivistic thinking in computational architecture? With the explicit arrival into architectural vocabulary, a defined operational language occurs with definitions related to empiricism[18].

Ill. 034 *Associative/Parametric geometrical constraints*



Geometrical relations defining behaviours of design solutions in a logical language. It is possible to purely alter the design through this model view, and by that only operate in constellations and constraints.

The showed illustration defines the geometrical output and behaviour of Experiment 2, page 94.

Descriptive order is constructing geometry in physical and mathematical relations of which problems are measurable and attended. The language described as a new universal language do also have remarkable resemblance to neo-positivistic thinking by Wittgenstein, who was concerned with the logic of language capturing things, events or facts, rather than nature itself.

If a scientific language is suitably constructed it could, through its logical structure, capture the very logical form of the world. [Wittgenstein]

Though Wittgenstein hardly had computational architectural scripting in mind, shown examples and definitions illustrate this line of thought surprisingly well. Associative and parametric relations are constructed through environments, which do not progress architecture through 'things' (walls, roof, ceiling, stairs etc.), but with the relations capturing it. In science, where computational architecture indeed is placed with collaborations including computer scientists, mathematicians and engineers a rational set of argumentations are indisputable in the perspectives of Technocrats[19] who only accepts this way of procedure.

Techné

In dissecting the term technology, diversity is found in its two constituents, revealing technology as being more indistinct in definition and open to phenomenological related expressions. Technology originates from the Greek 'technologia', dividable into 'techné' (craft or art) and 'logia'. Techné is described as craftsmanship or,

'It is the rational method involved in producing an object or accomplishing a goal or objective' [www.wikipedia.com, 2007]

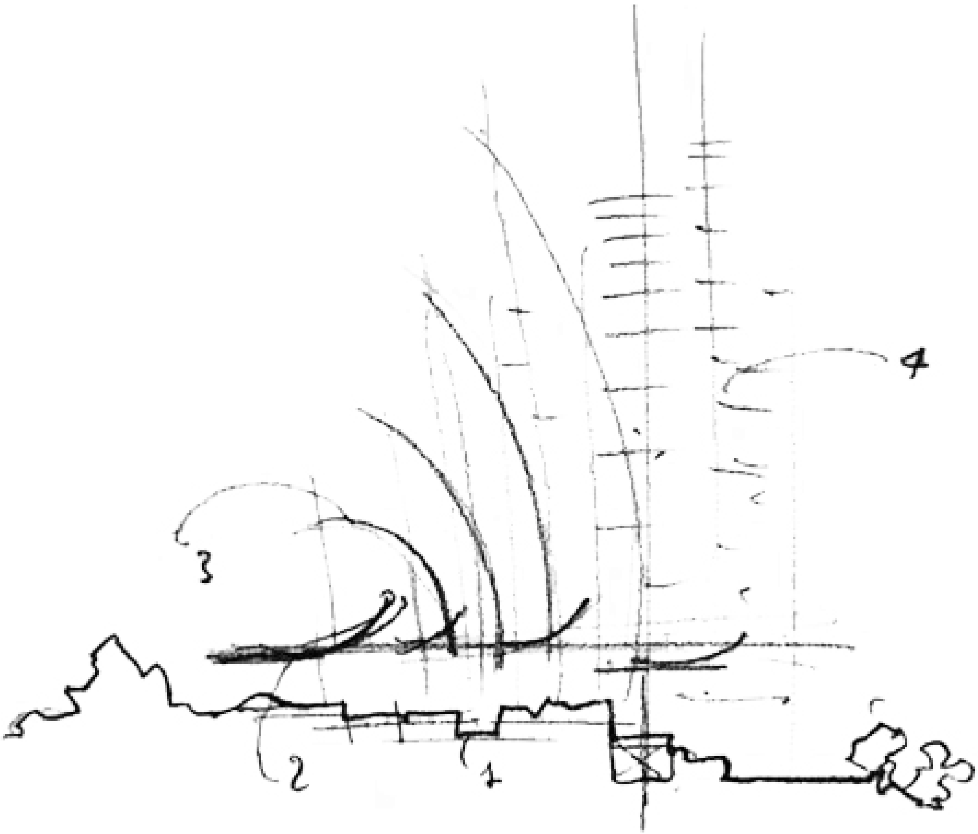
Hence being defined as a process established by technology and art. Techné thereby separates itself from the definition of contemporary technology solely based on knowledge, whereas techné frames both knowledge and art as process. What defines techné is thus the presence in the creation of an artefact and not in the production. Techné can then be described as the means of which the architect connects technology to art, through the creation.

A path in theoretical notions towards merging of art and technology is then recognised. Technology can then be seen as a process towards art and not as art itself. But how is art then identified in computational sustainable architecture?

Art

However technological interventions rapidly enter the built realm to improve conditions for human habitat has it not yet been able to confront essential subjects as 'being in the world'[20]. Sustainable architecture addresses the subject directly through philosophical terms as they attempt to connect to the ecological system on earth through its design parameters of natural forces (wind, sun, water etc.) and their presence influencing human 'being' in the

Ill. 035 Tijbaou Cultural Centre, by Renzo Piano Building Workshop



The drawing illustrates a section of the Tijbaou complex, with thoughts to sun, wind and the surrounding landscape. Art is thus captured through the relation to site in form language, material use and changing weather conditions.

world. To change the environmental catastrophe, a fundamental change in human behaviour and our values of 'being' are required [Wines, 2000].

If we re-enact earth as living connectedness, then we are called to see our place (being placed) in/on the earth in a transformed, enlarged way. We need, then to re-inhabit our place. … To re-inhabit is to relearn dwelling. [Heidegger]

Responsiveness to context and the ability to transform behaviours and living conditions are thus important aspects of phenomenological implementation into architecture of all kinds. In fact,

Art conveys truth and art should be revealing the truth of context, in which it is created and the purpose, which it should fulfil. [Heidegger, 1994]

The truth of context can relate to various miscellaneous elements such as sociological conditions, historic references and particular site circumstances being for instance environmental parameters. What is of importance is the reflectance or revealing of the contextual elements in the building in order to be truthful. This phenomenological definition of art in architecture suits the intentions of computational sustainable architecture through the process of which design is based upon.

In the connectedness lies a differentiation and separation from prior ideological idioms and technologies, which in many contemporary sustainable projects are present despite knowledge of their damage. Art, as a derivation of phenomenological understanding beyond the solutions of pseudo-sustainable architects and engineers, is a necessity to reach levels of re-inhabitation described by Heidegger. The notions of technological driven solutions towards ecological plausible results are in the perspective of phenomenology not possible – unless conveying to the truth of context.

Equilibrium

In using the theory described above, we can confine what relations of the two perspectives and their joint interaction must be part of creating sustainable architecture through computation. In the aim of a building driven by both performance requirements and aesthetics, equilibrium of technology and art must be reached. Through imbalance, by an excessive technological methodology and with that a building relating only to its performance-orientated solutions, the prospect of negligence arises towards intention and context. In contrast, suppressing technological interventions and the construct of building by technical means, a piece of art is conceived without essential properties of functioning as a building.

In much contemporary sustainable architecture the negligence of either one of the two perspectives is present [Wines, 2000]. Looking at the continuous development of artificially constructed internal spheres, relying on technical implants, from housing to enormous commercial

Ill. 036 *The Channel 4 headquarter by Richard Rogers has resemblance to industrial machine factories, constructed in steel and glass.*

Ill. 037 *Contradicting to the industrial architecture are Earth ships, constructed from reused materials and lowered into the ground, using the warmth from the Earth.*

centres, a clear image renders of a desire to distance humans from its ecological habitat and the 'being' formulated by Heidegger above. Opposing the scientific solutions of a sustainable world has 'comic' solutions been suggested and to some extent built [Wines, 2000]. These are, however the good intentions, often of poor architectural quality and fails just as often to maintain comfort standards comparable to modern living.

Insertion

A partial conclusion in the importance of both knowledge spheres to be present has already been established. Further comparison can be made to the definitions of Knowledge and Heuristics by the perception of thought to promote deeper theoretical implementation to process and thereby reached the means of accomplishing profound sustainable architecture in a digital age. Art, described as a sensing and 'being' relates to heuristic operations through the human mind and chose, whereas technology is associated with knowledge and procedural positivistic operations. To define strictly where art is placed in an architectural process would be brave, but also stupid and ignorant as each architect develops creative thinking in different design environments. Considering that the formulated design schemes support a fusion of methods between analysis, evaluation and synthesis even more suggests the impossibility of pinpointing where art is 'developed' in the creation of a building.

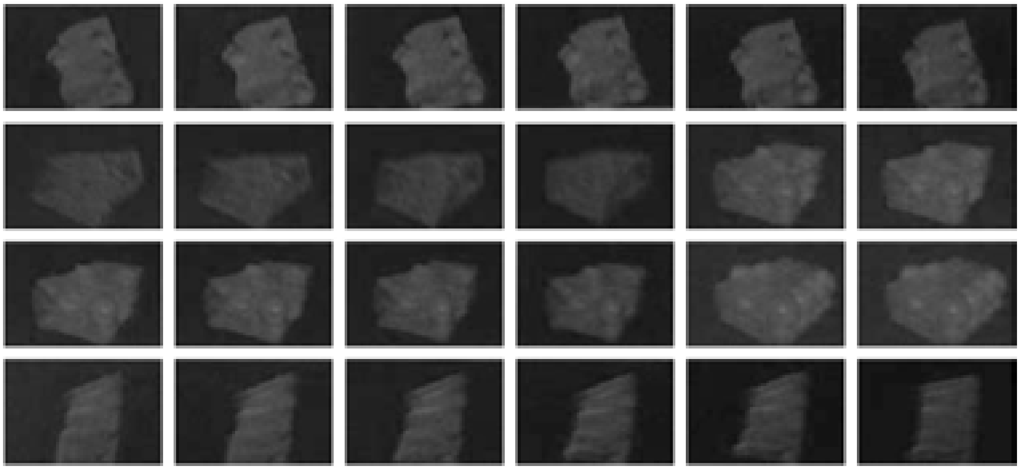
Importance of art, as defined above, must though be recognised in both process and as the end result of merging positivistic and phenomenological processes with the aim of computational sustainable architecture, though numerous attempts in sustainable design has tried to show otherwise through a pure belief in technical solutions.

Realising technology and art in architecture, as process and result is dependent on the architect and what liberation of control he/she engages into in computation. Examples of dismantled control in e.g. Motion-Based formations, evoke design randomness in relation to context, by technological constructs. But here the computer alter according to sensing, leaving the human interpretation behind, or at least to be suppressed to only choosing the right key frame. In performance based formation, which we prior defined as the digital way forward, letting loose to optimise geometry et al, is also conducted through computational manoeuvres, however not to the same extend as Motion-Based formations. Can computation in this way fulfil the descriptions of technology and art, when referring to sustainable architecture?

3.3 Control and chaos

The following chapter continues the argumentation of perspectives from the prior chapter in the scope of successful implementation of digital means into sustainable design and confronts the idiom of the creative control from the architect. In this case, control refers to the architect being in charge of the creative process, while chaos is a synonym of the computer-

Ill. 038 *Keyframe based formation from deformation*



Part of a long series of keyframe outputs from a house prototype informed and generated from surrounding observed sound and movement forces.

Design by Greg Lynn Form

generated creative process, though one must admit that the opposite could just as well apply in many situations.

As established through positivistic theory, do technology suit the architectural path towards performance design well. The idea of computation through its core – the coded language – is digital operations, which is advancing the process. Technology being process can then be further explicated as it advocates that computation can be applied in creative processes of conceptual character and not only in optimisation.

Keeping the notion of the performance based formations, an input must prelude computation, parameters to generate upon, which suggest a sensing source of inspiration, being the designer. Subjective analysed elements is thus fed into a design engine to generate upon, whether it being in search of conceptual form or improved thermal properties. Experience based, subjective analysis or contextual mappings are thus transformed into usable computation data, constructing performing form being one of the primary motivations for this project. Iterations looping between designer and computer – control and chaos – constituting the basis for sustainable architecture, technology and art, framed by the interleaving process scheme formulated in earlier chapters.

It is essential to incorporate the human explication of computational performative design schemes to promote architecture balancing between technological extremes and purely sculptural artefacts. Therefore are computational performative processes as singular creative entities not capable of reaching sustainable architectural design.

We ought to be careful about trusting a new technology to create perfect solutions on its own. [Kolatan, 2005]

The advice given by Kolatan marks an experience based reaction to the introduction of digital tools in architecture and must be taken serious in our search towards a better architectural discourse. Understanding the potentials and downfalls derived from computational randomness or chaos is unmistakably central to use the full capacity of the media from solutions to conceptual studies. Some even argue that computation is not part of conceptual form finding at all.

Architects who operate from a design standpoint might be interested in shape grammars and all kinds of other computer-generative design issues (...). For us it's a bit of a curiosity as to why the designer would give up design to a machine anyway. [Glymph, 2005]

It seems by the statement given from one of the leading digital design based practices, Gehry and Partners, that they are defensive of the evolution or have settled with using computation as a link between design and construction, not idea to design. This can be explained by a computational approach that seeks to make sketches in two dimensions into

Ill. 039 *Sketch by Frank Gehry*

Conceptual sketch by Frank Gehry to be used for 3-dimensional modelling, to perform cost and construction analysis.

complex three-dimensional buildings in reality. Computation is via the methods used to make the wildest sketch realisable, instead of performing iterations with the aim of improvements to a conceptual idea or as a way of innovate architectural design. Thus the approach remains in an advanced version of CAD models defined in Digital Definitions by Oxman.

Extracting knowledge definitions

Whenever applied, experience and theory formulated in this work, emphasises computational performative form finding as being part of an interleaved design process, supporting positivistic and phenomenological methods in joint effort. Knowledge levels and knowledge spheres presented are seen to be essential parts of defining computational sustainable architecture as a whole together with the process formulated. It thus lays the groundwork for experimental research for novel sustainable solutions.

In clarifying above knowledge perspectives from the merging chapters, a series of knowledge constructs are shown to define constellations of thought taking part in a computational sustainable design process.

Computational sustainable architecture;

a) Relies on heuristics in start phases, with deep knowledge implementation in analysis, evaluation and synthesis phases.

b) Can only be reached through the merge and equilibrium of phenomenological and positivistic approaches – technology and art, both as process and result, through the human percep tion of being to inform the rational process 'engine'.

c) Must accept 'chaos' towards form finding and optimisation, effectively guiding towards performing form.

As with the formulated design scheme, are defined knowledge implementations not a prescriptive list. However, it is believed that the above stated definitions considerably improve the conditions of the interleaved design process, better architectural quality and performance requests in sustainable architecture.

Progression path, knowledge levels and spheres and space for intuition have been formulated. To operate within the process scheme and incorporate knowledge perspectives, explication of computational sustainable methods are necessary. The following chapters seek in that necessity to illustrate different methods through examples and experiments with growing level of complexity.

4.0 OPERATIONS

As a prolongation of Processing and Merging chapters and a final architectural constituent to define a framework for computational sustainable architecture, Operations are added in displaying methodological potentials of computational operation with above definitions.

The following chapters will explicate emergent techniques, which strongly influences the possibilities of investigations into environmental viable solutions, sustainable parameters and strategies via examples and experiments. 4.1 Emergence illustrates in that aim emergent strategies through morphogenetic systems and rational modelling, while 4.2 Research foundation introduce technological and sustainable elements and parameters influencing the design progression to be followed by 4.3 Experiments envisioning conceptual form finding, to lastly seek to conclude upon the Operations chapters through 4.4 Conclusions.

In the linking from the interleaved process, through merging concepts to operations are operational scales located. Further examples and conducted experiments are all defined through an operational building scale of departure and subsequent alteration. In computational sustainable architecture are urban relations, building, façade, internal spatiality, geometrical and material properties singular and connected entities.

Last mentioned (geometrical and material properties) are of particular interest in the emergence of behaviours and thereby the performance searched for in all levels to evolve form.

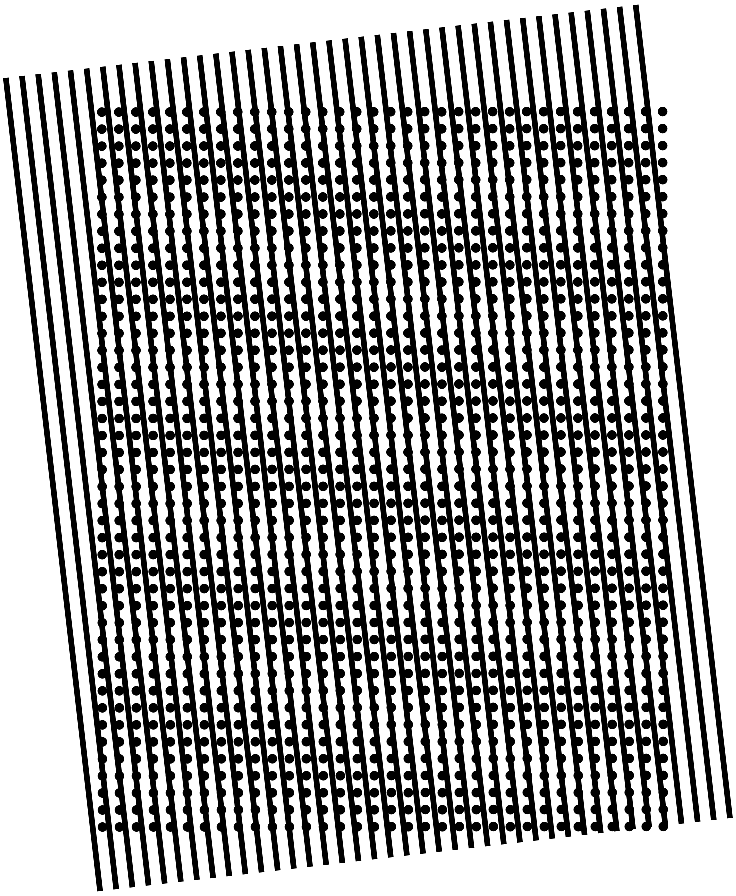
4.1 Emergence

Emergence can be explained as the process of becoming into being. It thus relates to a process of making. In Latin, the term describes unforeseen occurrence[21], which frames the essence of the meaning in this work. Importance of emergence is significant to computational sustainable architecture operations and relates directly to the definitions reached in Merging through the necessity to incorporate 'chaos' in the conceptual process to improve performing form. Emergence of form can be exemplified via the Moiré effect (Ill. xx) where two patterns overlap and create a new emergent result. The emergent order or form is not predictable and will create outputs through systematic variations of its constituents. The same procedure and variation occur in parametric operations in architecture through alteration of relations [Height, 2006].

Local variations of the components work at an entirely different scale from the global which emerge. [Height, 2006:p.355]

Scales are thus interlinked in operations, from local constellations to overall form and expression, as also advocated through the formulated design scheme. A micro level (defined as structures of a material or geometry similar in scale to the fibres in a plant stem) driven

Ill. 040 ***Moiré effect***



The Moire effect is constructed from two periodic patterns, which through overlaying creates a new emergent pattern, which will dissolve or change according to the positions of the original two patterns.

alteration can in this perspective provoke emergent results on building scale. The computational approach towards form finding through micro levels can be reached via shape grammar as described at page 24 in which growth parameters generates form or as adaptable systems implanted into a greater system through associative/parametric modelling. If the constituents/components (micro level) are developed upon sustainable strategies, a form will emerge from sustainable driven parameters. Form is in this way described and progressed from 'ground level' conditions, informed in its matter to develop solutions from first stages of design.

Components

Material sciences are through focus towards internal behaviours of natural systems developing new territories for exploratory architecture and the arrival of morphogenesis[22] in architecture dealing with natural mechanisms, systems and orders relating to the above described use of levels in architectural performative form finding. This enables separation from static environments (in both process and solution) to prior techniques and results, supporting the desire to frame dynamic static's in performing form and enrich the architectural components in their aim of being human habitat, through improved internal properties. The dynamic terminology used is not contradicting the prior described distance to kinetic architectural solutions, as the alteration is non-geometric, but solely a change in material behaviour though properties of phase-change[23] conditions in geometrical optimised positions according to information feed (the environment).

The inherent differentiation in material properties enables more fluid connections in spatial arrangements referring to dynamic parameters as weather conditions.

Light conditions and acoustics or thermal gradients can be used to differentiate spaces, especially when aligned with topographical manipulations, and these fluid thresholds are intrinsically dynamic as the time of day or season varies. [Weinstock, 2006:Introduction Morpho-Ecologies]

Dynamic contextual parameters are consequently being captured in operations altering applied components in greater systems and are as a result an adaptable system within a greater system as formulated above. Organising operational methods in computational sustainable architecture have through the constellation of interleaved process schemes and an approach through adaptable components resemblance to biological behaviour and optimisation as described through morphogenesis.

Biological forms are systems within systems, hierarchical arrangements of semi-autonomous organisations [Weinstock, 2006:p. 28].

This supports the organisational path of working with several scales simultaneously with the aim of local and global optimisation and form finding. The following examples and experiments are in the line of argumentation built upon the concept of systems within systems. Most of the illustrated design scenarios operate with two systems, a) a parametric defined component constrained by a weather parameter and b) an associative host system in which the parametric system is located.

In exemplifying the concept of operating with systems in systems a simple project developed by Arup's FII unit (Foresight, Innovation and Incubation) is illustrated to understand the principles of use and subsequently the profound strategies that have the possibility to emerge from such an approach (especially with the imagination of more advanced architectural endeavours).

A new media centre in Paris has through this approach optimised its indoor thermal conditions based upon a series of components or systems applied to another topological defined system. The system is simple but generates a diversity of 4.2x10298 different solutions in a single box. Four different panels with varying transparencies and thermal properties are placed according to internal programme, optimising indoor spatial functionality and individual comfort (Ill.043). In spite of a somewhat used Euclidian typology, an interesting effect can be reached as a result. The possibility of re-organising the entire envelope according to changes in spatial programming, have immense possibilities during the process as vast design scenarios can be simulated and altered instantly.

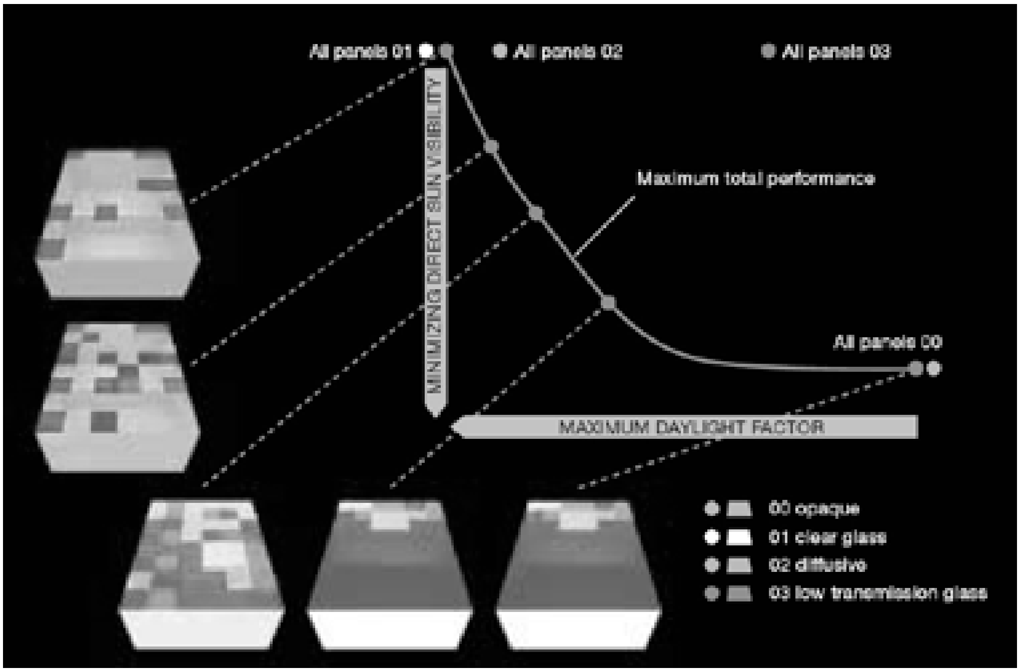
In this example, the applied system alters, while the host system maintains unchanged. To improve the global system an optimisation of both systems must be considered and incorporated to inform all scales towards better results, returning to the argumentation of separating sustainable architecture from modernist idioms.

To perform similar and improved experiments as the illustrated media centre, a series of requirements must be considered and understood. The following chapter explain through a description of parametric notations and sustainable parameters, being computational sustainable building blocks, what prerequisites most be obtained.

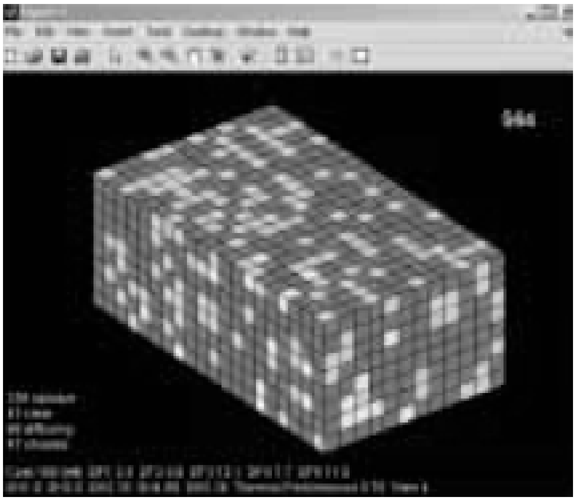
4.2 Research foundation

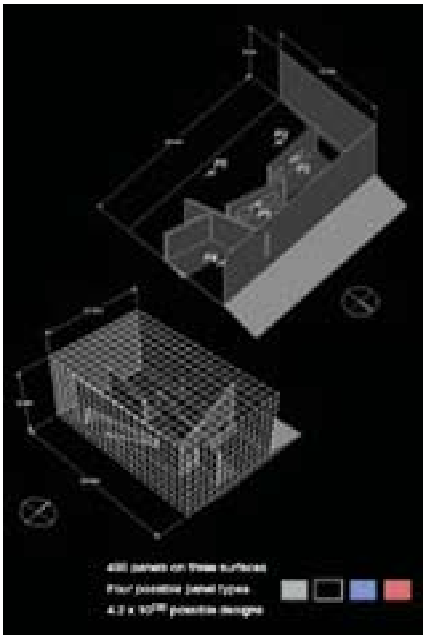
The creation of an aesthetical building involves in vernacular architecture many elements, which should be considered and implemented. Computational sustainable architecture adds as a minimum knowledge effecting sustainable parameters, their effect, their solutions and simulations environments together with computational skills in managing of computational environments and a logical mindset [Aish, 2007]. Complexity and knowledge levels thus grow to inform form in conceptual design phases. The two added factors, sustainable and computational, are through the chapter explicated to facilitate operations and experiments in the following chapter, 4.3 Experiments.

Ill. 041 **Paris Media Centre**



Ill. 042





Ill. 043

Sustainable parameters and strategies

The scope of this work is by far to construct a complete description of sustainable parameters and strategies. It nevertheless is important in engaging computational sustainable architecture to know what lies behind heuristic decisions. Prior case studies reveal to some extent sustainable factors, but without explaining how. It is recognised that many mechanical systems improve the conditions upon which sustainable architecture can advance. Though this is the case, those elements will not be included in this work, hence focusing on passive strategies as the primary means. The chapter thus seek to illustrate knowledge of effecting factors; sun, wind, topographical and material entities in brief descriptions.

Further activation of the parameters can be recognised in an impressive variety of novel solutions implemented to archive better indoor climate and surrounding external spaces. Prior techniques to the industrialised society, in the absence of unlimited resources, work as complete passive integrated systems with different purposes responding to context. Though computational sustainable architecture rely on highly technological creative design tools, understanding and use of passive strategies are essential to develop innovation. Former concepts thus infiltrate the conceptual ideas of constructing conceptual performance models. Each of the sustainable parameters can in this way be exemplified in pre-industrial architectural strategies, not only optimising comfort but also contributing to a regional vernacular architecture.

Sun/parameters: Solar energy can be seen as the main resource in sustainable architecture, but also as a main contributor to discomfort in buildings, through temperature imbalances. The penetration of solar energy and radiance through the building envelope is therefore essential to absorb energy in winter and reflect energy in summer. Extended reduction in energy can be reached through good daylight conditions due to a decrease in electricity used to power artificial light, which also improves PPD[24] (Predicted Percentage Dissatisfied) values.

Sun/strategy: Maximising solar gains to equalise temperature balance from day to night, summer to winter, is possible through thermal mass, subsequently storage of thermal energy. It is possible to store energy in different materials, but overall properties of materials must be obtained. In general the material should have a high density, high heat, low thermal conductivity[25]. The strategy can be applied in all climates, with most effect in regions with large temperature differences. Such differences can be found in Kuwait where response can be observed in buildings made of thick heavy walls of local stones. In daytime the building absorb the solar energy, in a process where indoor temperatures decrease, while releasing it back to the interior space during night when the exterior temperature decrease[26].

Wind/parameters: Effectively the source for natural ventilation, which has two primary aims; lowering temperature levels and exchange air to lower particle and CO_2 levels[27]. To obtain comfort levels and avoid SBS[28] (Sick Building Syndrome) an effective system must de imagined and designed due to the topographical conditions and internal usage conditions. In some

Ill. 044 *Thermal mass and energy storage*
Kuwait Parliament designed by Jørn Utzon

Heavy stone forms the Kuwait Parliament, stabilising temperature while preserving vernacular architecture.

regions, natural ventilations even have the capacity to pre-warm inlet air. A balance, as with solar energy, must though be reached to not cause draft, lowering comfort levels. Extension of the natural ventilation can also be improved through thermal buoyancy[29], directly related to the design of the building positioning and height.

Wind/strategy: Mangh, or wind catcher in English is the name of a more than 500-year-old technique used in Hyderabad, Pakistan [Battle, 2002], to increase ventilation through a building and to let solar energy warm the interior spaces. The 'catcher' face southwest, towards the summer winds. The 'catcher' is open during the night to ventilate the building and to close of solar energy during day. This is reversed in the winter period, to profit from solar gains during day, while the winter wind direction is from north, unable to enter through the 'catcher' [Khatri, 2005]. Though this strategy requires a manual interaction through the opening and closing manoeuvre it still present a passive techniques through the knowledge and use of solar paths and wind directions according to time of the year. They furthermore implement knowledge of thermal buoyancy through vertical extension of the chimney.

Topographical/parameters: Relation to place through contextual elements including history and surrounding urban fabric and/or nature, to which influences sun and wind factors, movement of people and material references. For sustainable architecture to prevail with above definitions of positivism and phenomenology, topographical relations are of considerable importance.

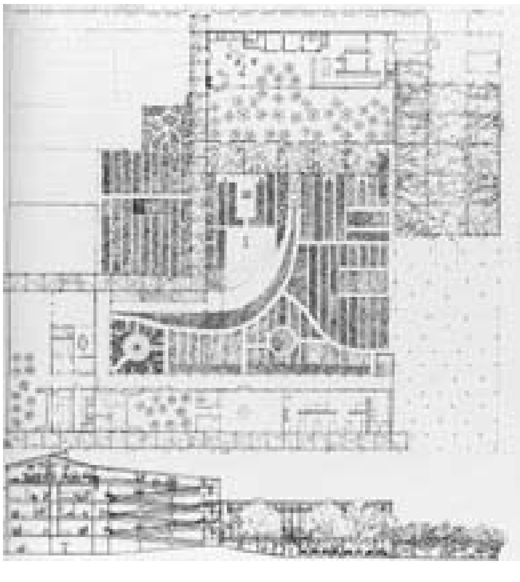
Topographical/strategy: By contextual implementation of surrounding programme, being urban or landscape, a melting of boundaries occur offering a social and topographical approach to which sustainability can be reached through a merging of spheres, shared and used [Wines, 2000]. Greenery and building thus materialise together in the creation of a site-specific building, relating to sociological and environmental factors. Envisioning the merge of topographical factors can be seen in Eva's Kitchen, in which Troy West shelter a 60.000 m2 courtyard created from a series of brick buildings, to frame an appealing social centre, illuminating the interiors and creating a greenhouse also functioning as a sunlit dining room for the inhabiting nuns.

Material/parameters: Prior described material interventions are changing circumstances for which sustainable architecture can be created. Material as an element or source, compared to sun, wind and topography can be seen as the physical constituent of sustainable architecture. The contemporary development and importance of material behaviour and properties thus justify its presence among the other three sources of energy and inspiration. New materials improve thermal values, resistance and endurance. Smart materials can be informed with phase-change[30] properties and react to changing conditions. Contemporary wall systems[31] are facing a maximum depth, as the U-value[32] (thermal heat conduction through a given area of a wall) cannot decline through adding insulation. Materials construct the building, but must also be seen as a larger constituent to a successful sustainable solution through the use of local materials (lowering transport to building site), reuse of materials from prior constructions

The image of wind catchers from Mangd in Pakistan, serves as important lesson in the use of natural ventilation. A refined strategy, adaptable over the course of the year with little user interference.

Ill. 045 *Natural ventilation strategy*
Wind catchers in Hyderabad, Sindh, Pakistan

Ill. 046 *Topographical strategy*
Melting of spatial entities in sustainable perspectives



Social frame and improved climate is the result of a spatial organisation and use of vegetation. The social space becomes a cultural, social and topographical meeting point within the interior landscape created.

and waste management to not pollute with building wreckage. Material choice thereby becomes part of a greater system beyond the designed building.

Material/strategy: Materialisation of architecture are in most projects a necessity and consequently with high importance to the outcome in aesthetical as well as performative relations. Steel, glass and concrete have been heavily used since the beginning of the industrial revolution (also illustrated in the cases investigated in Processing) and exchanged the prior use of bricks as main building component. Without rejecting the material revolution with above-mentioned smart materials et al, bricks have been recognised with several sustainable properties; high density (thermal storage), durability, reusable and an aging process often improving the aesthetic expression. In addition are structural strength and highly flexible assembly possibilities supporting the material system in freeform language. In elegance and use of material properties Eladio Dieste shows a profound use of brick assembly in which structure becomes art through knowledge of its behaviour [source]. The structural intelligence can be extended with sustainable potentials through awareness of solar exposed surfaces and penetration of the highly configurable system.

Though the exemplification of sustainable parameters and principles are of brief character (with the detailed research conducted in mind), an outline of primary factors is seen to enable heuristic operations in computational sustainable architecture. Engaging the sustainable parameters and possible use of pre-designed strategies is done via two computational methods; associative/parametric modelling and shape grammar.

Computational modelling

The contemporary architectural tools illustrated in Digital definitions and incorporated in Processing and Merging for performative design solutions and thinking, are framed by associative/parametric modelling and shape grammar. The computational techniques have been chosen due to capacity of control and capacity to develop performative form (see definition p. 20). Both being computational and operative in the software Generative Components[33] from Bentley Systems and compatible with various simulation environments serve to avoid data confusion and errors through format transfers[34]. Both techniques rely on relations and constraints to develop design, thus heuristic inputs are compulsory.

The following experiments (developed methods) are conducted through one of the two techniques, depending on the chosen operational scale and component, which simplifies the input data rate to improve operational overview and to develop singular concepts/methods implemental in different conceptual process situations and design scales.

Parametric constellations and sustainable strategies are in each individual experiment/method described, as model 'set-up' from base parameters is required each time. This naturally constructs a high level of early input, but offers through customisation a highly adaptable model to work and generate from.

Ill. 047 *Material strategy*
Behavioural understanding of material properties
Cristo Obrero Church, Uruguay, designed by Eladio Dieste

The curvilinear wall assembly constructed from rectangular brick, creates a dynamic force flow possible to configure to demand.

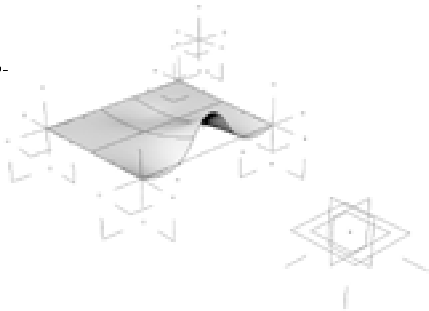
4.3 Experiments

Conducted experiments are individual pieces of work, separated in computational constellation, sustainable strategy, scale and complexity. They are as such representing different operational scales suggested earlier. Despite their variation in aim and intricacy a common series listing points to evaluate their potentials defined from computational, process and sustainable perspectives. All experiments/strategies relate naturally to topographical parameters, through either sun or wind, but neglects in the absence of a defined location other topographical elements described above. In isolation from a complete series of effecting forces, a method is derived possible to implement in conceptual form finding.

Following points of evaluation are seen to describe the potentials of each experiment.

[1] Aim
[2] Concept
[3] Architectural element
[4] Parametric constellation
[5] Sustainable potentials
[6] Process potentials

Ill. 049
Local system component



EXP.001/SURFACE PENETRATION

[1] Aim
Developing a surface suitable for implementation in the envelope of a building. Form adaptation according to variable parameters is searched on component level. Component refers to a smaller defined part of the surface area.

[2] Concept
First generation experiment is investigating the parametric relation between an associative surface and a moving point, representing the sun. Openings are controlled according to the placement of the point to which generates a gradient form development over the surface area.

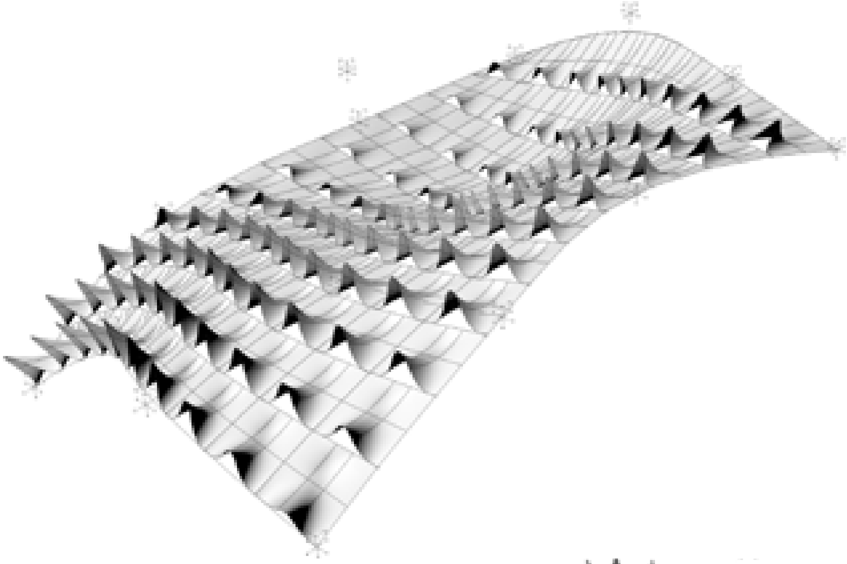
[3] Architectural element/Operational level
The surface is imagined to be a complete roof or façade, thus an operational scale relating to both a smaller part of the building (the individual component) and to the expression of a building envelope (the geometry of the surface).

[4] Parametric constellation
The model is constructed via two main components; an associative surface and a parametric feature - a system in a system. The two are in principle independent entities but merged to offer form flexibility and variable control of openings. The feature can in fact be applied to any geometrical defined surface and still adopt its constraints to predefined rules.

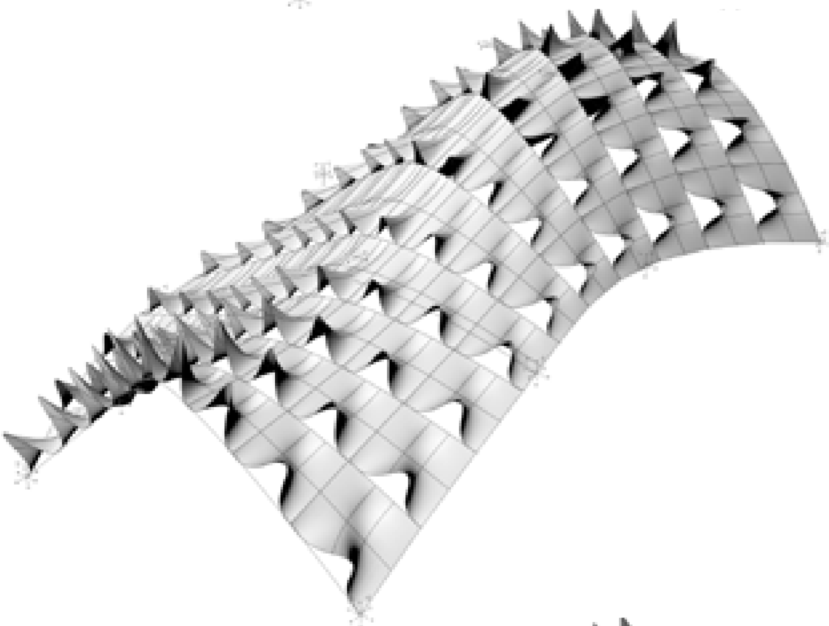
[5] Sustainable potentials
Solar studies through analysis of surface penetration are of interesting character, as the surface develops according to the moving point. This allows a direct link between the path of the sun and envelope expression. Applying the necessary lux level behind the surface can then alter a complete façade or roof.

[6] Process potentials
Solar levels and energy penetration simulated offer feedback for form iterations with complex geometrical solutions as result. A variable is implanted to adjust the effect of the opening, which conceptual form can be instantly reconfigured from. A series of solutions can be created and subsequently simulated according to visual expression and performance results.

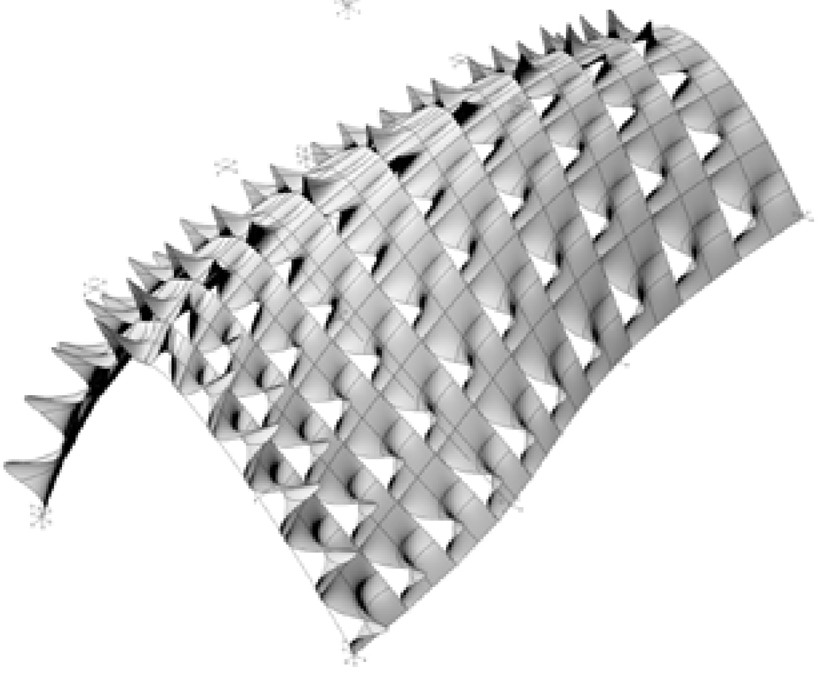
Ill. 050
Surface modulation with external parameter creating a differentiated opening ratios over the surface.

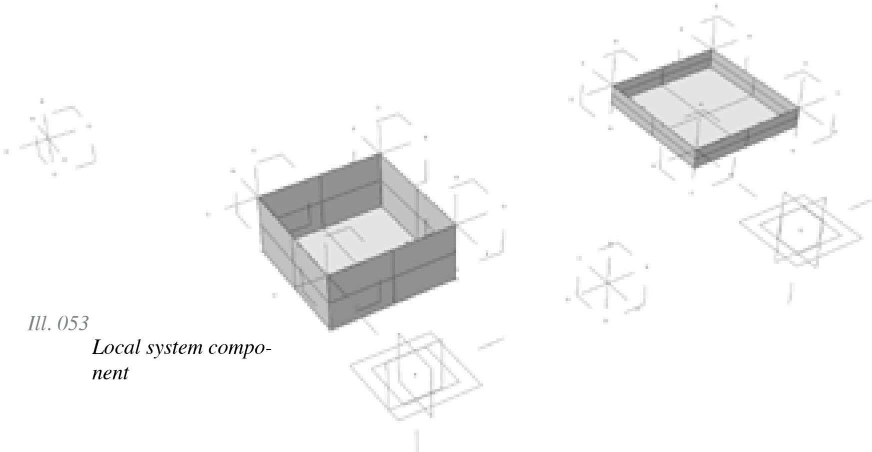


Ill. 051
Vertical modulation of surface, altering openings according to changed relation between surface geometry and external parameter.



Ill. 052
Surface modulation creating an interior space with same performative respond to prior modulations.





Ill. 053
Local system component

EXP.002/SHADING

[1] Aim
The construction of a volume, representing a morphological tower structure, enabled to change its overall geometrical constellation by moving control points and changing parametric constraints. Further to develop a feature that adopts its depth, to pursue optimised shading conditions from world orientation.

[2] Concept
An old strategy applied in the New York Times Building from 1905, by Eiditz & McKenzel was to deep-set windows to help shield interior spaces from direct sunlight. The same concept is implemented in the parametric model to adjust the depth of the windows in a complex geometrical form, which updates simultaneously with the changing of the shape according to designers wishes of visual expression.

[3] Architectural element/Operational level
The element designed operates on component scale (smaller part of the greater system) to which another designer can design from in building scale. The experiment is therefore functioning on two scales with two architectural elements (the window and the building geometry).

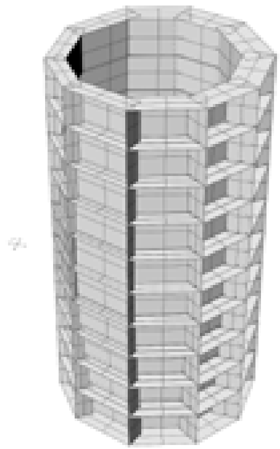
[4] Parametric constellation
The model is constructed in the same way as the adaptable surface from experiment I. This means an associative volume and a parametric feature. The feature is in this experiment a direct responding to the conceptual idea, as it changes the depth according to the world orientation. Offsetting the deep part of the window is parametrical defined by the relation to the overall geometrical system.

[5] Sustainable potentials
By constructing an adaptive model with shading constraints the designer is offered a tool that gives freeform handling without loosing the optimum solutions for control of direct sunlight. Implementing sustainable strategies even before modelling and then have a system simultaneously designing with the changes of architect gives an interactive operational design environment seeking to optimise environmental conditions, even if the architect has little knowledge of how to design functional shading systems.

[6] Process potentials
In a morphogenetic form-finding process on conceptual level, is the parametric constellation becoming a tool for iterative processing in very fast design evolution, letting the system be an active partner to the designer as respond to shape alteration instantly is visible in the model without running simulation software for detailed analysis. The conceptual process here refers directly to the concept of a 'Solution' before creating a solution formulated in Processing.

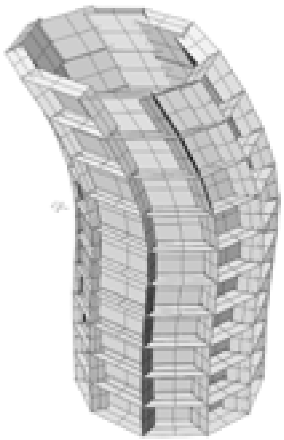
Ill. 054

Straight tower, symmetrical in all axis, with equal window depths.



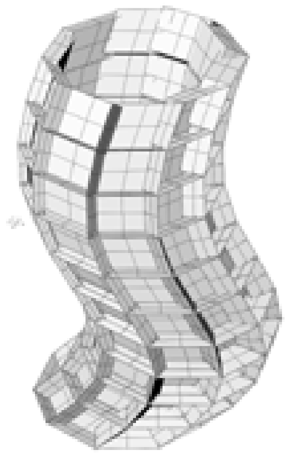
Ill. 055

Tower stretches, deforming the geometry in one axial movement.

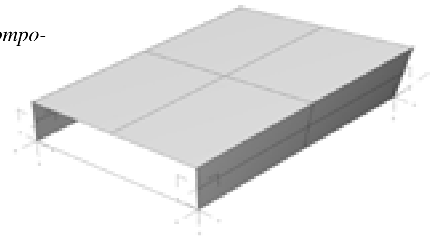


Ill. 056

Bending the tower in two directions to which the window depth will reconfigure.



Ill. 057
Local system component



EXP.003/ZONING

[1] Aim
To develop a system for controlling individual light conditions in different zones of a building, that can be applied to simple and complex geometrical shapes. For the reason of simplification, in contradiction to the earlier two experiments, it is the idea to create a geometrical language beginning with Euclidian shapes. This improves the possibilities of compatibility in thermal simulation software for iterative processing and for reasons of fabrication possibilities.

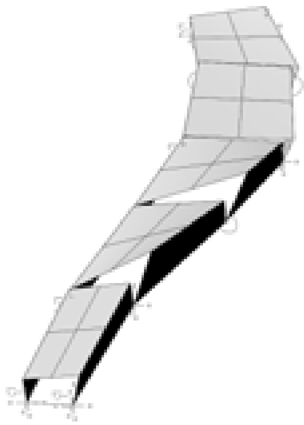
[2] Concept
A rectangular box is derived into a twisted volume opening its geometry to the adjacent twisted box by constraints to a moving point. Individual components define the openings in different areas of the overall geometry (building) in relation to the same variable parameter – the moving sun. Infinite components can be constructed to as many different zones existing to pre-determine the penetration of sun through the surface of the building.

[3] Architectural element/Operational level
Alteration geometry is designed as a component populated onto a system, but in a scale shaping the building body, rather than functioning in a set geometrical expression. This experiment thus confronts alteration of building form in a set 'footprint'.

[4] Parametric constellation
An associative grid is modelled to be a platform for the induced components. This means that the components construct the overall building geometry and thereby not only become and implant as designed in EXP.001 and EXP.002. The building body is in this way altered through each of the designed components' constraints. Parametric alteration is then raised in scale from component level to building shape. As mentioned, an infinite number of components can be made to serve the complexity of the task, in this experiment the number of different components is set to six.

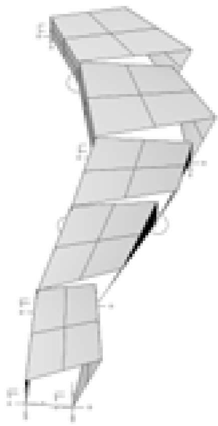
[5] Sustainable potentials
Buildings are naturally designed with a great variation to internal programming, all with different needs for daylight conditions, solar gains and view to the outside. Designing components with different constraints to their openings and then feed the system in accordance to the spatial programme offer a direct activation of design development from presets of spatial organisation.

[6] Process potentials
When feeding the designed building with many various constrained components, a change in the need for e.g. different light levels due to changed spatial conditions or unsatisfying simulation feedback, can fastly be handled by changing component parameters redrawing an unlimited series of façade openings. The iteration between form development software and simulation software can then be maintained in a conceptual design process.



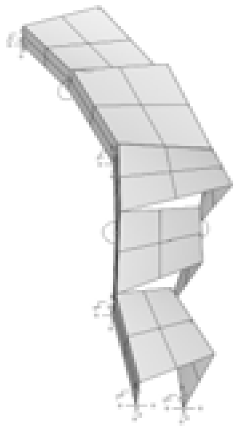
Ill. 058

Global geometry populated with local system, with external parameter forcing opening in bottom of illustration.



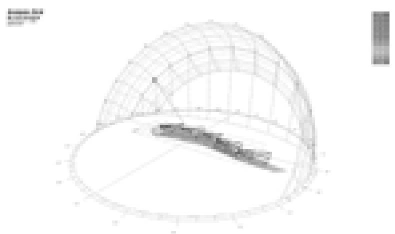
Ill. 059

Global system opens in top part of illustrations as a respond new input.



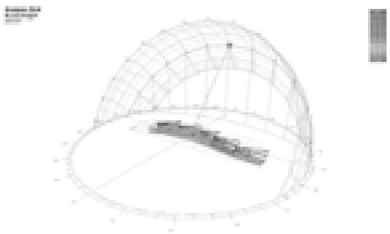
Ill. 060

Shape opens in centre by new information.

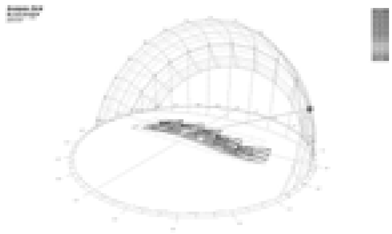


Ill. 061

Daylight conditions as respond to pre-programmed system.



Ill. 062



Ill. 063

4.4 Experiments conclusions

As operational constructs serve the experiments to illustrate implementation of computation with sustainable input as a performance driven approach. The strategies are based upon heuristic knowledge in different building scales, with the idea of explicating potentials of parametric models with a complexity level usable for early design phases. Deformations based upon prior sustainable strategies enabled by computational systems offer thereby a new entrance to form development with embedded environmental functionality. The strategies can in this way be seen as a step further than the strategy presented through the Paris Media Centre, due to a geometrical optimisation in local and global scale of the building.

To improve the performative models, investigation of material systems must be implemented to higher degree as well as a further development of the geometrical relations, improving the conditions for adaptability towards comprehensive performative systems, responding to information input related to the parameters listed in research foundation.

A research into more complex organisations of material and geometrical systems will be done through a biomimetic approach applied in the design part of the project to direct the strategies more towards an application. Natural systems are as described systems within systems optimised in performative organisations, adapting to its host environment, to which an investigation of natural principles can be a catalyst for architectural performative concepts.

5.0 FRAMEWORK CONCLUSIONS

The idea of formulating a complete framework for the merge of computational and sustainable strategies is naturally of optimistic character. As the fields of interest are in strong development, a conclusion to the formulated processes, definitions, concepts and strategies is as such impossible to give. Despite of the uncertainty within the researched subject, the work illustrates, describes and arguments positions and methods which can shape possible sustainable projects through computation. It is believed that the framework clarifies and enables better performative processes in regards to both process and end result due to the holistic frame in which the developed theory is implemented – from process schemes to operational strategies via knowledge implementations.

Extending the potentials of the design frame is done when the individual designer do a further optimisation of the formulated framework by creating a hierarchical structure of the strategies, for them to perform in an optimum way in each design scenario, thus scaling value parameters according to the premises of location.

As a continued research, a design project is developed to clairify and exemplify the constructed theoretical concepts into practice with emphasis on the conceptual design approach through geometrical and material systems. The design phase serves in this way as a pilot project relating to contextual properties of physical and phenomenological character.

6.0 DESIGN INTRODUCTION

Implementing the developed strategies, theoretical approaches and sustainable concepts via architectural computation requires a building scale and programme, which allow the mentioned aspects to be fulfilled.

The chosen design project is a library in multi-ethnic Raval in Barcelona.
The Municipality of Barcelona has provided the project location with the intent to create a new cultural entity for places in underdeveloped city zones. Project programme is chosen through the idea given by the local municipalities through an open project concept, which allow designers to create both building programme and building design. Barcelona is contradicting to many other cities managing to create libraries as public, informational and social entities to which a growth in their use has been measured over the last decade. More local libraries are scheduled for in the nearby future. The building programme is a respond to that demand.

The chosen building programme is a small library, seen as an extension to Catalunya Library, located next to the project site. The new part is based on digital and paper-based sections with diverse studios seeking to create a library that frames culture, knowledge and meeting rather than being a depot for books. It should be a building that improves the city zone's functional foundation and a help to improve the educational, social and environmental aspects through the strategies presented earlier.

6.1 DESIGN METHODOLOGY

A successive path was constructed through the theoretical chapters to clarify the formulated argumentations. The same line of concept is used through the design process, which evidently built upon the schemes, concepts and operations. The design methodology can be divided into three parts serving the formulated theoretical concepts, linking each other; information - formation - form.

Information

Informing a system with performative data is a direct path towards a performing design, which needs to be treated with the parameters described during the theory. Information of contextual elements (topography and weather) together with the spatial programme, creates an informational layer readable as explicit data (lux levels, wind speed etc.) and as diagrammatic implementation (urban movement, pedestrians and cars).

Formation

An adaptive system is based upon the data developed and studied through the information part, creating an architectural entity reflecting chosen formation conditions implemented into a global and local adaptive system, whos visual starting point is based upon the topology study. Information and heuristics create the parametric design systems described as the 'presolution' formulated in the computational design scheme page 47.

Form

Form is consequently developed through interleaving iterations of contextual, programmatic and climatic conditions, shifting between 'control and chaos', forming the library through parametric/associative relations towards a performative architecture.

Despite entering a more traditional architectural process phase, are the premises for computational sustainable architecture different, through a generative form engine constructed by the pre-solutions, combined with a directed process path with solar, wind, material and topography as its pillars, differentiated by the hierarchy provided by the designer. Deep knowledge is implemented in larger parts of the evaluation to see the physical effects of the heuristic operations performed within the FORMATION chapter.

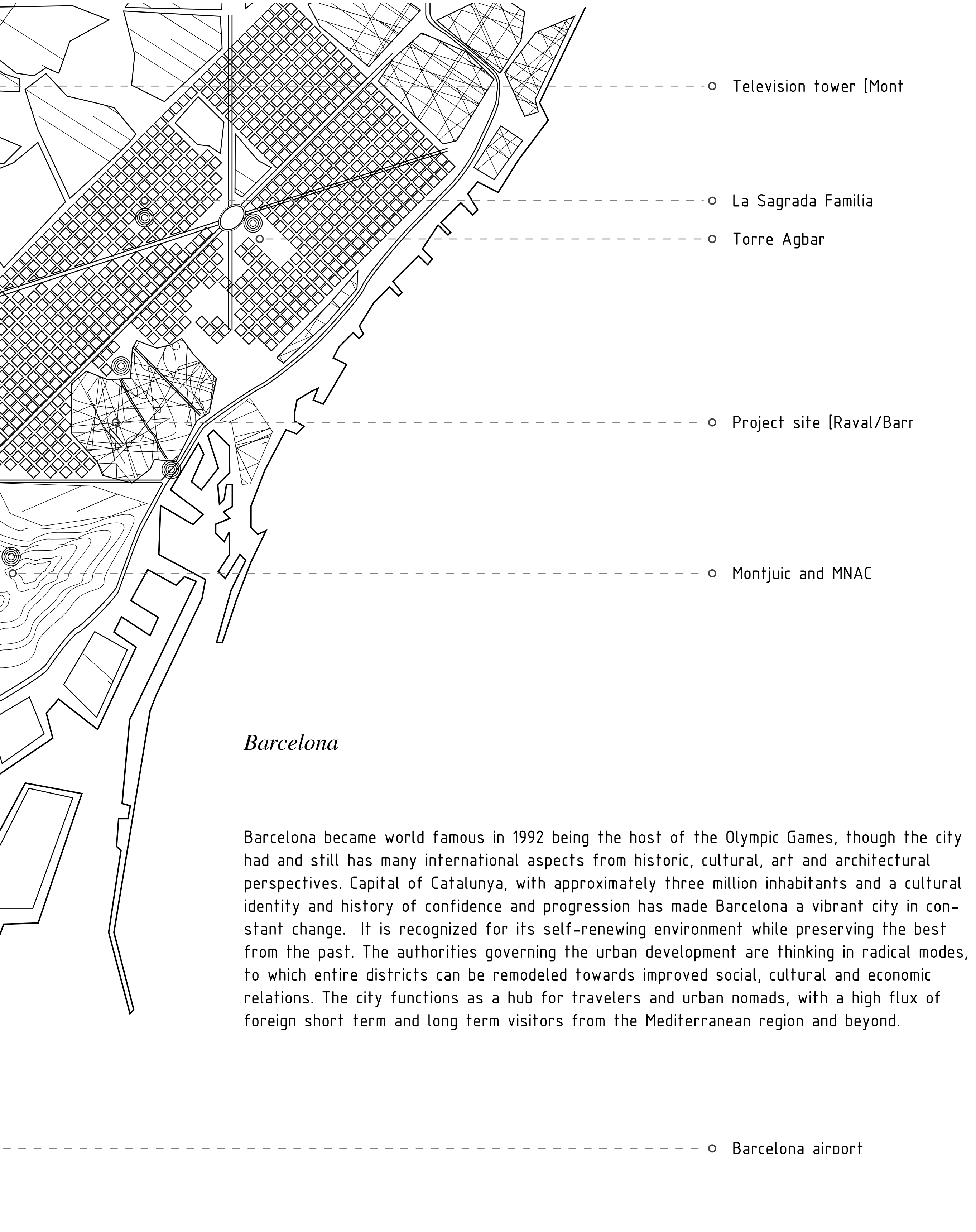
6.2 INFORMATION

Contemporary architecture can be based on various types of information and can be as confusing as conclusive. Information feed towards sustainable architecture is searched through the 'Operations' parameters (page 84). Environmental data is thereby mapped for solar data and wind data and topographical data is mapped through contextual programme and contextual movement of pedestrians and cars. An understanding of the location from region to project site is seeked via a description in three different scales - Barcelona, Raval and Placa Gardunya,

The information section has the aim of identifying cultural, topographical and environmental elements usable as developmental parameters in the formation and form process.

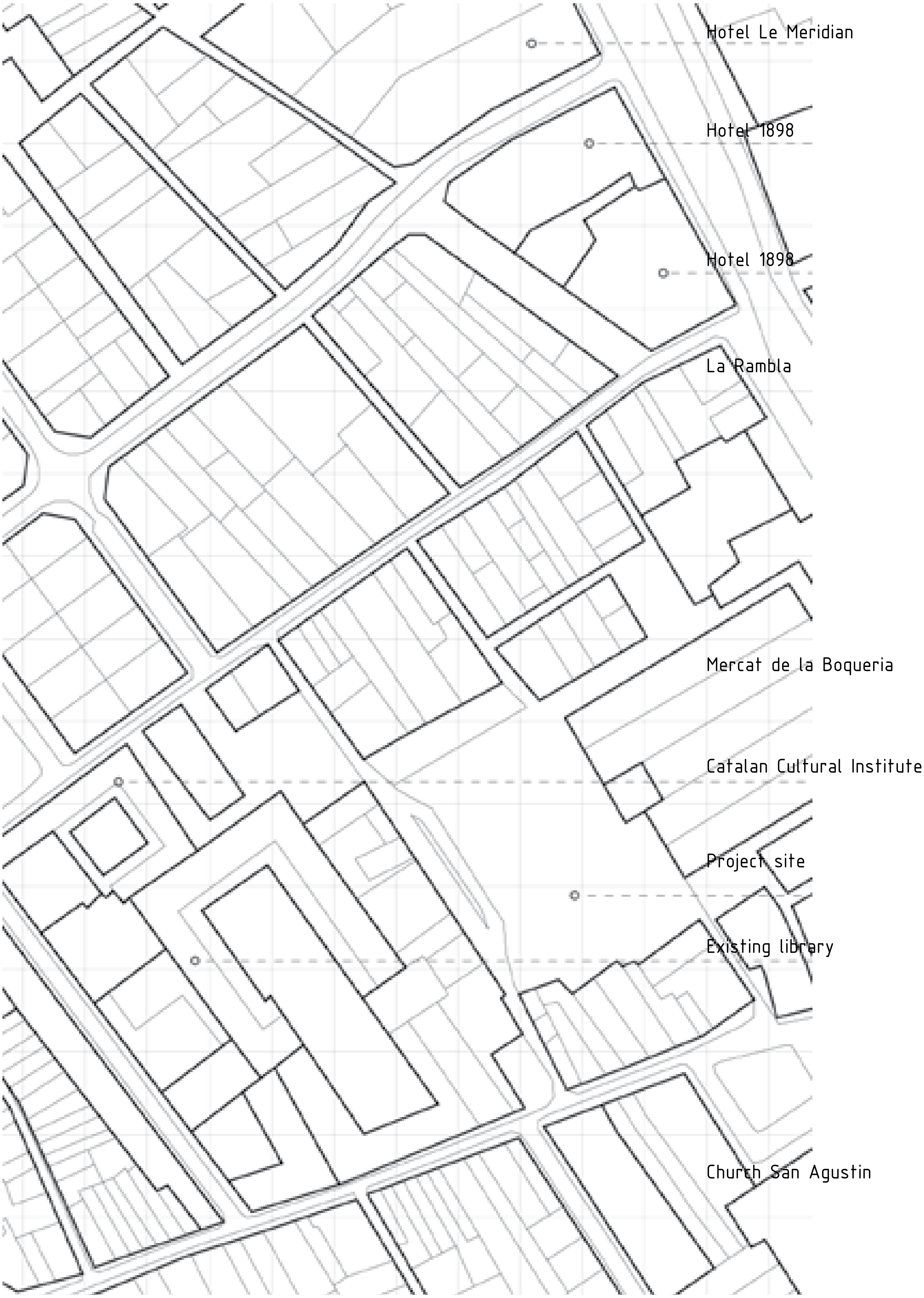
6.2.1 Contextual Mapping

Ill. 067



Barcelona

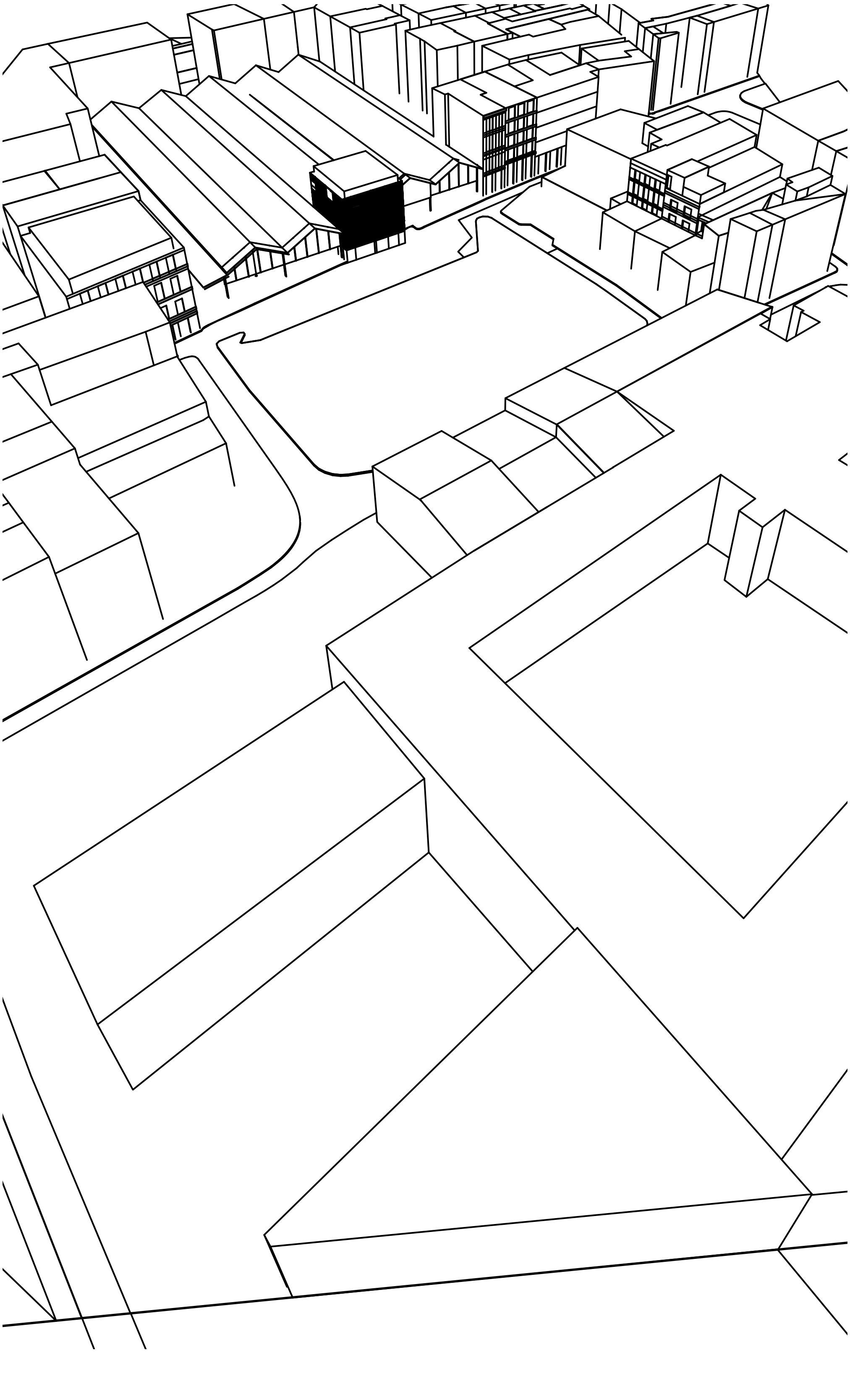
Barcelona became world famous in 1992 being the host of the Olympic Games, though the city had and still has many international aspects from historic, cultural, art and architectural perspectives. Capital of Catalunya, with approximately three million inhabitants and a cultural identity and history of confidence and progression has made Barcelona a vibrant city in constant change. It is recognized for its self-renewing environment while preserving the best from the past. The authorities governing the urban development are thinking in radical modes, to which entire districts can be remodeled towards improved social, cultural and economic relations. The city functions as a hub for travelers and urban nomads, with a high flux of foreign short term and long term visitors from the Mediterranean region and beyond.


Hotel Le Meridian
Hotel 1898
Hotel 1898
La Rambla
Mercat de la Boqueria
Catalan Cultural Institute
Project site
Existing library
Church San Agustin

El Raval

The city district located on the western side of La Rambla within the Gothic Quarter has been known as the Red Light District of Barcelona, with belonging dodgy bars, street girls, dark corners and poor urban fabric. Raval has a high concentration of immigrants from the East, which is mirrored in numerous Arabic shops, barbers, mobile phone shops, halal butchers and belonging street life. El Raval means suburb in Arabic and has for many tourists and locals been seen as place where not to go. This perspective has over the last decade changed into an image of the new vibrant and hip zone, packed with new fashionable bars, small art galleries, design studios and museums, to which a larger zone was demolished to then house Richard Meier's MACBA building and Rambla del Raval – a huge flat zone with palm trees stretching from upper Raval towards the harbour area.

Ill. 068



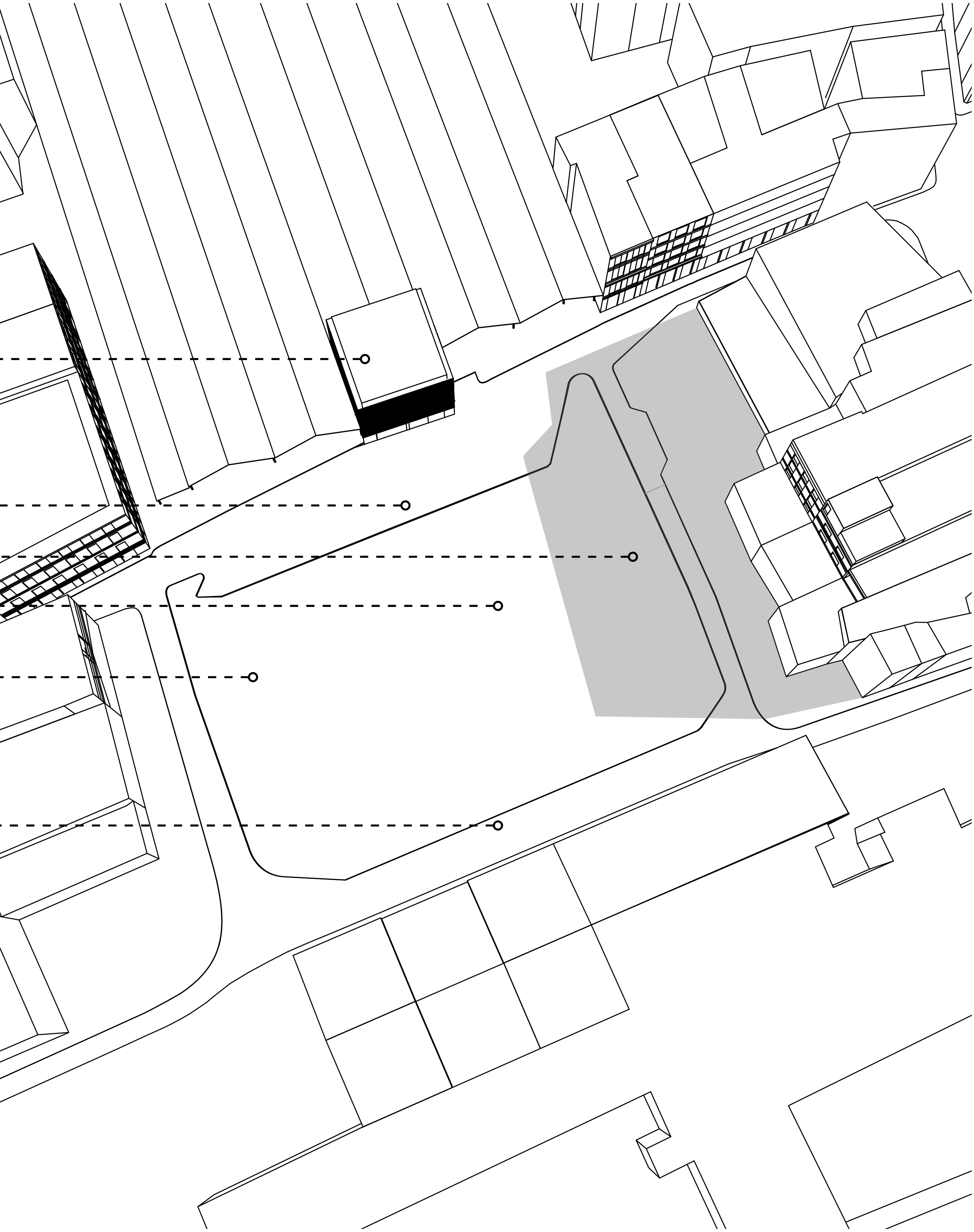
Placa de la Gardunya

Just hidden from the mainstream tourist routes behind Mercat La Boqueria is Placa Gardunya located, framed by the old hospital of Catalunya, residence buildings, cafes and the rear part of the market. Today the old hospital building is framing municipality offices and the library of Catalunya. The planar square measures approximately 60 by 100 meters, populated with cars in a gated area with extended underground parking. The building plot is located in the southern part against the existing buildings, stretching one-third into the parking area, which will be removed to give space for a new public outdoor space.

Ill. 069


Mercat de la Boqueria
Arriving food for the market
Site boundary
Gated parking area on ground
Terrace/cafes
Entrance to underground parking

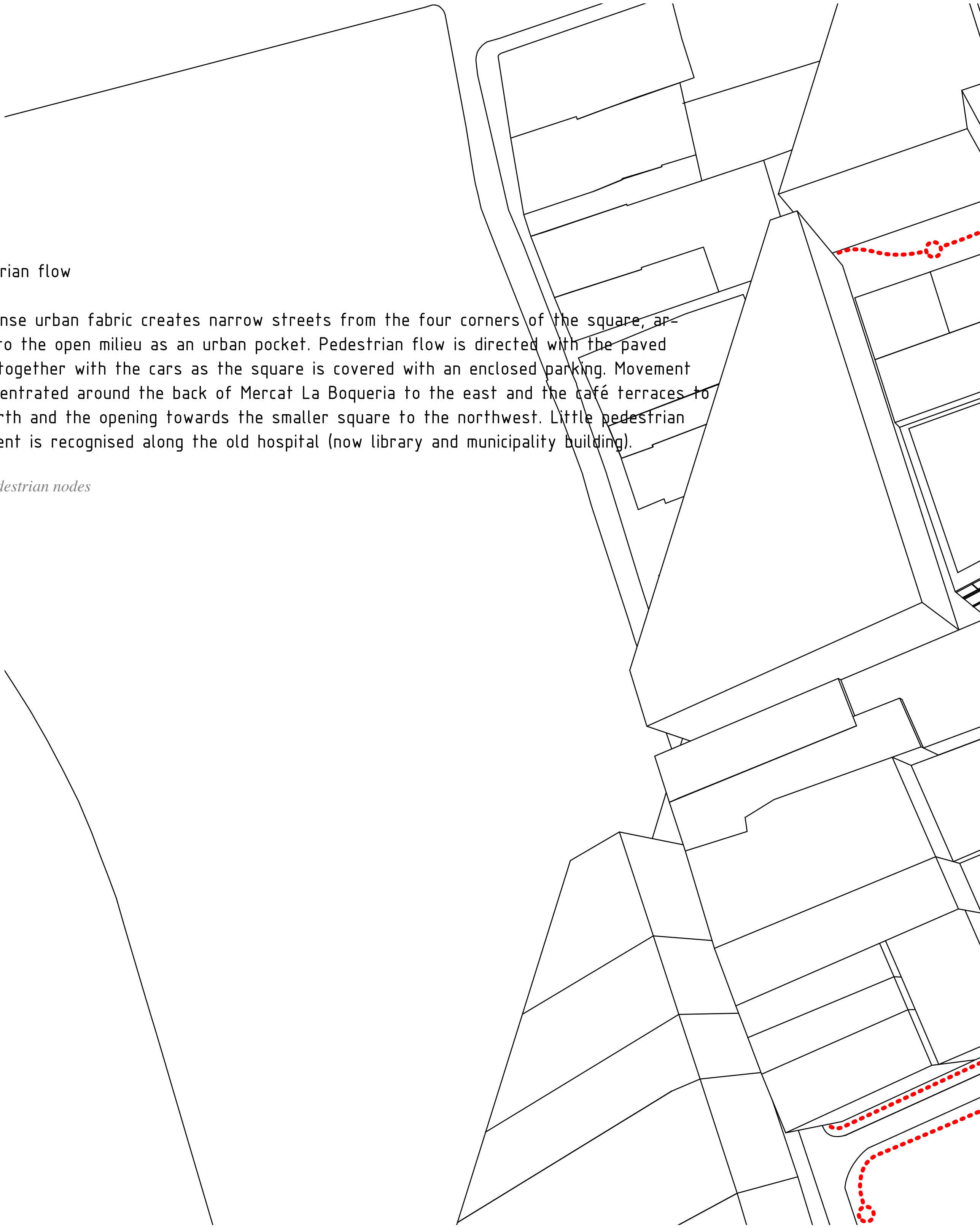
Ill. 070



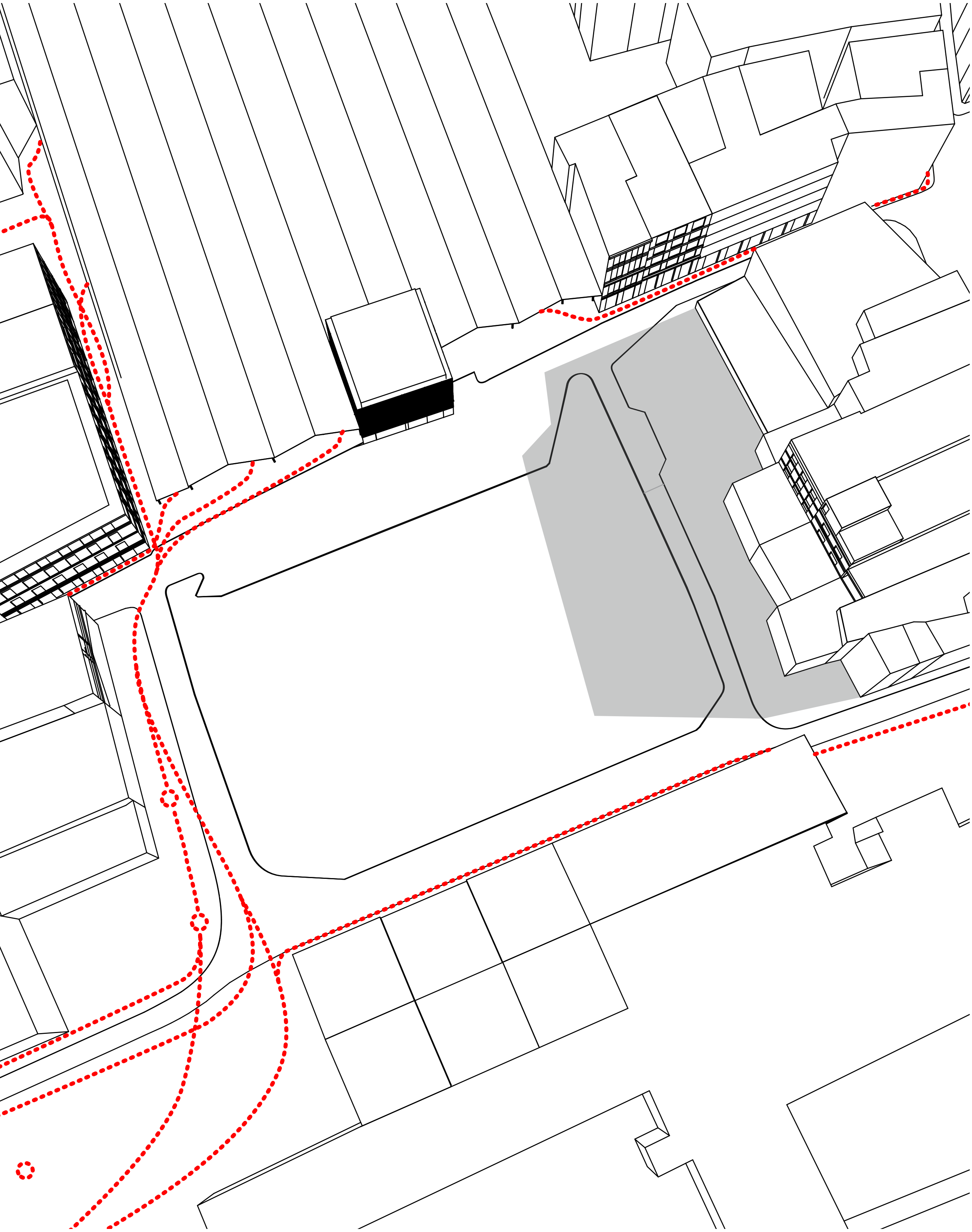
Pedestrian flow

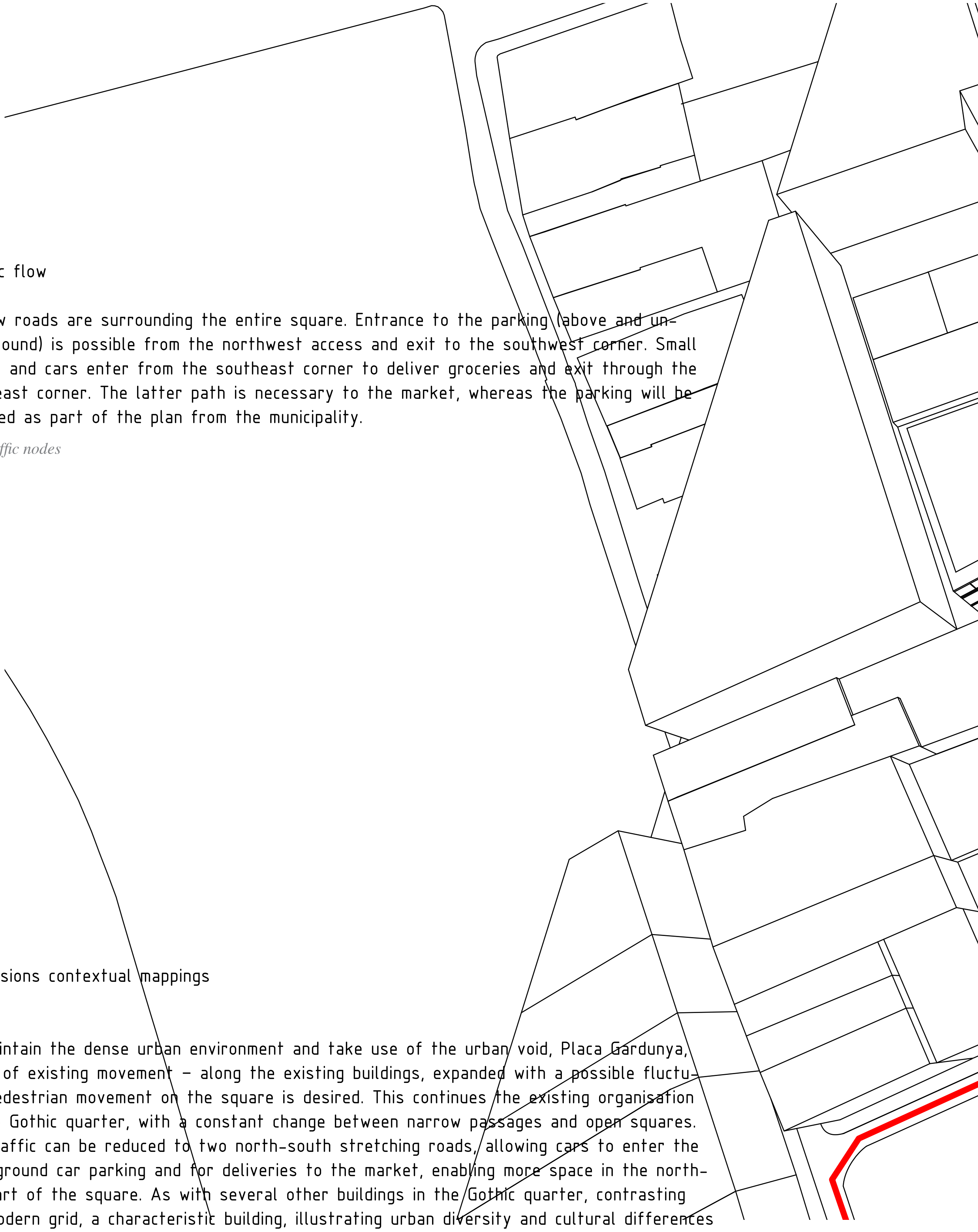
The dense urban fabric creates narrow streets from the four corners of the square, arriving to the open milieu as an urban pocket. Pedestrian flow is directed with the paved roads together with the cars as the square is covered with an enclosed parking. Movement is concentrated around the back of Mercat La Boqueria to the east and the café terraces to the north and the opening towards the smaller square to the northwest. Little pedestrian movement is recognised along the old hospital (now library and municipality building).

pedestrian nodes



Ill. 071





Traffic flow

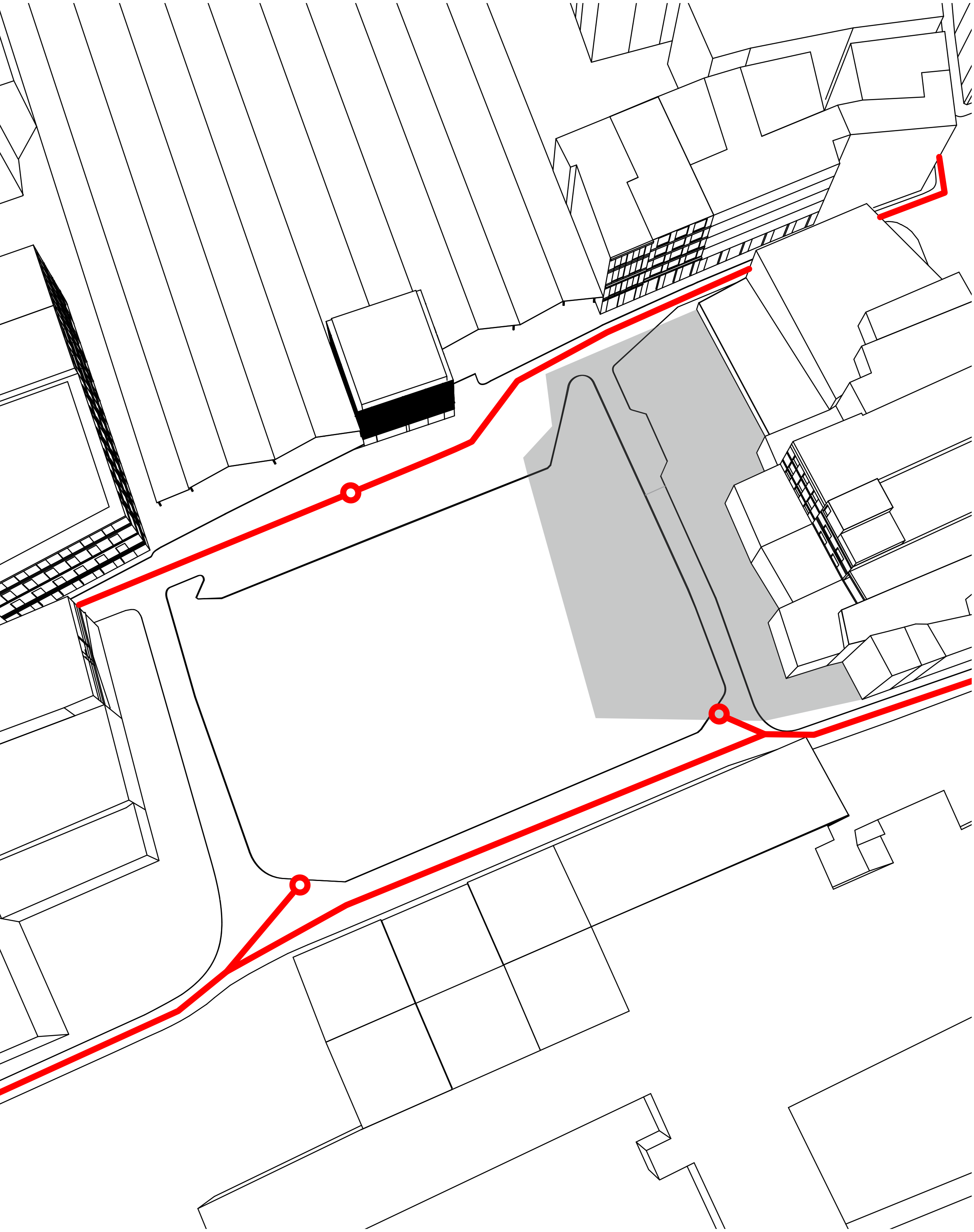
Narrow roads are surrounding the entire square. Entrance to the parking (above and under ground) is possible from the northwest access and exit to the southwest corner. Small trucks and cars enter from the southeast corner to deliver groceries and exit through the northeast corner. The latter path is necessary to the market, whereas the parking will be removed as part of the plan from the municipality.

traffic nodes

Ill. 072

Conclusions contextual mappings

To maintain the dense urban environment and take use of the urban void, Placa Gardunya, a use of existing movement – along the existing buildings, expanded with a possible fluctuant pedestrian movement on the square is desired. This continues the existing organisation of the Gothic quarter, with a constant change between narrow passages and open squares. Car traffic can be reduced to two north-south stretching roads, allowing cars to enter the underground car parking and for deliveries to the market, enabling more space in the northern part of the square. As with several other buildings in the Gothic quarter, contrasting the modern grid, a characteristic building, illustrating urban diversity and cultural differences will contribute to a future development aimed towards site-specific architecture reacting to contextual and environmental milieu.

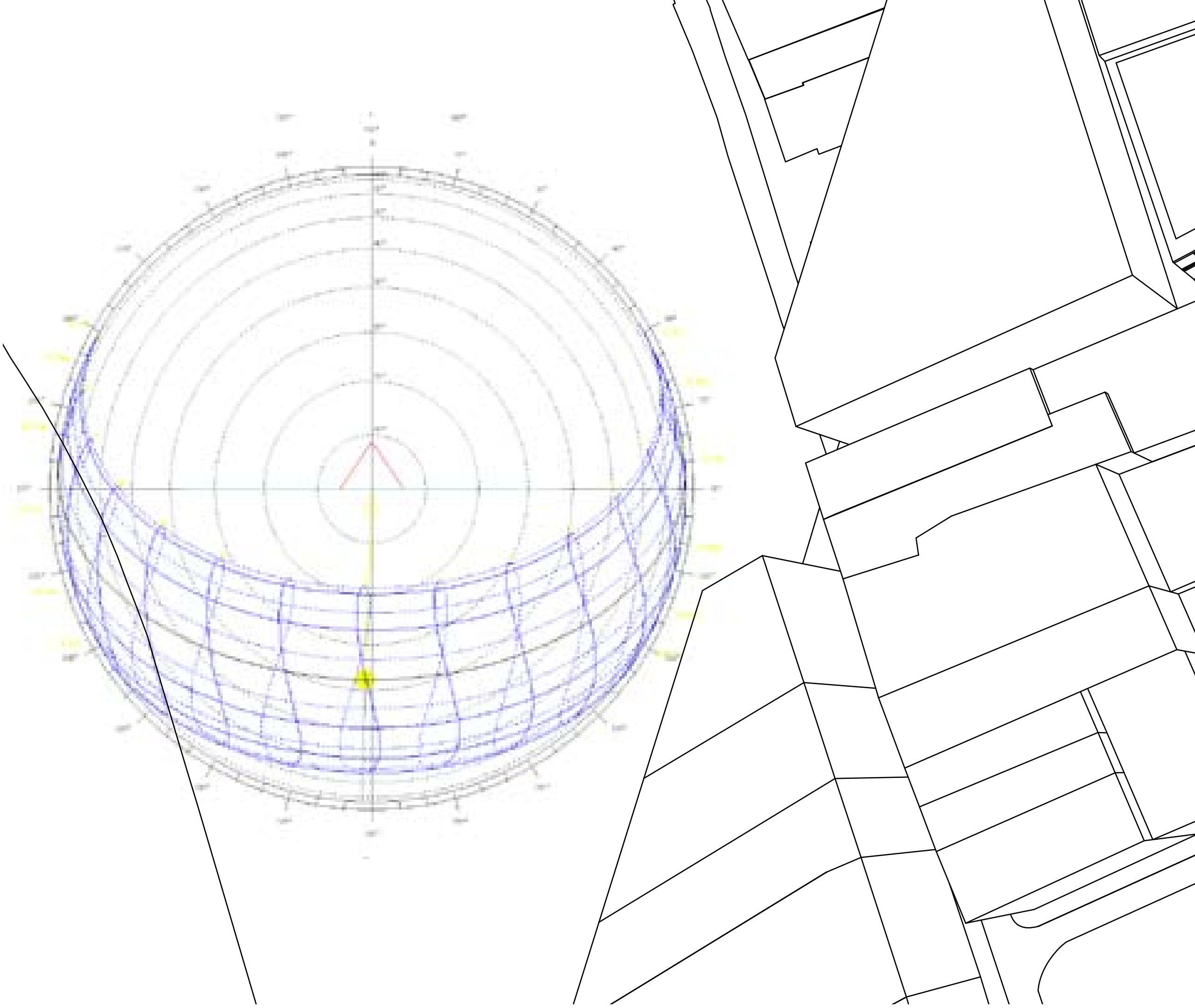


6.2.2 ENVIRONMENTAL MAPPING

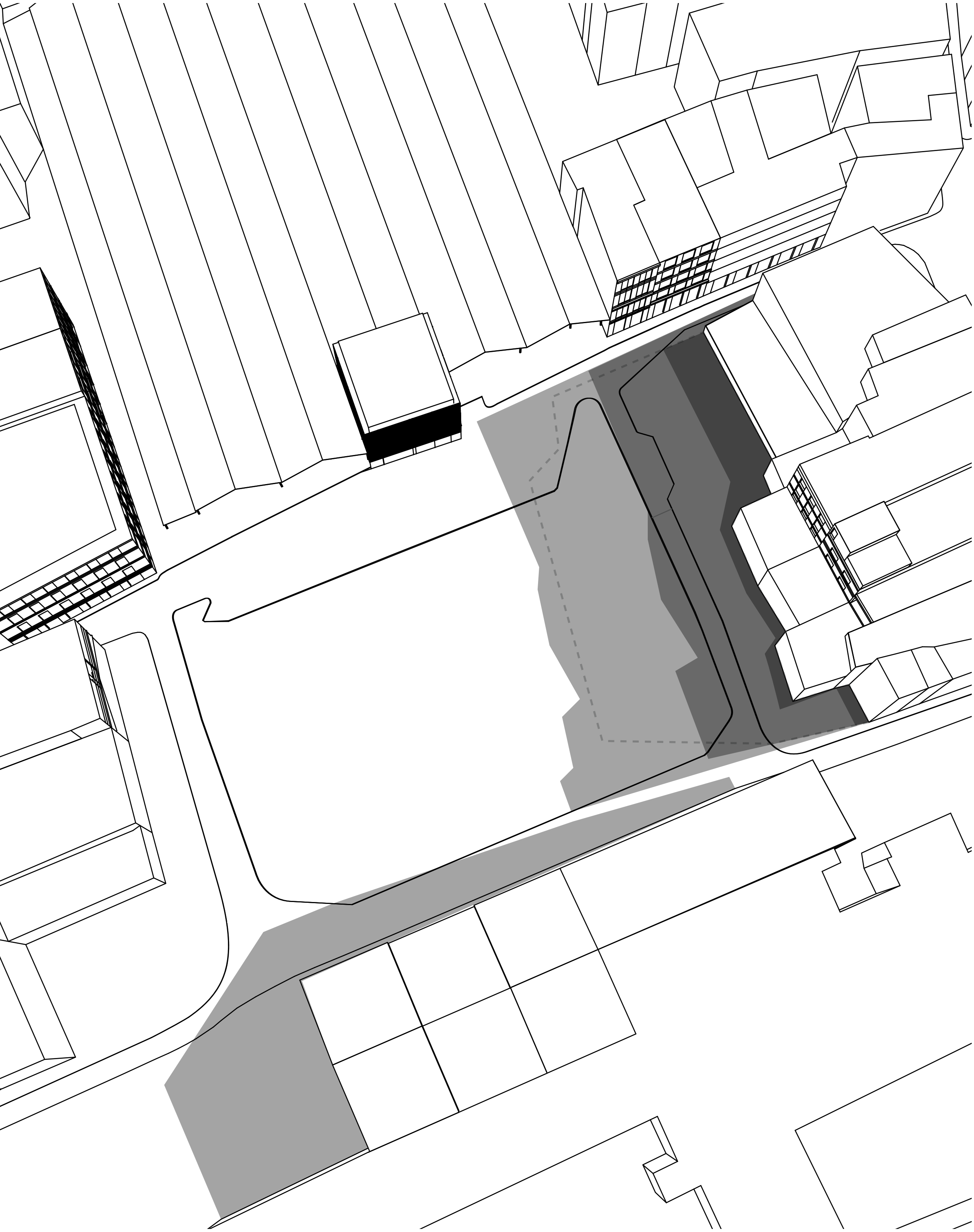
Solar information

Due to Barcelona's geographical location are solar paths azimuth angle high, with a near perpendicular position to the Earth in summer. To detect the movement of the sun a series of solar diagrammes have been analysed to create a database, reflected directly in a shadow diagramme and later implementable in parametric constructs to filter daylight in optimum ways.

The extensive amount of weather data is not illustrated here, as they digital models transfer directly from parametric to modelling to simulation environments. The data illustrated are from the software Ecotect.



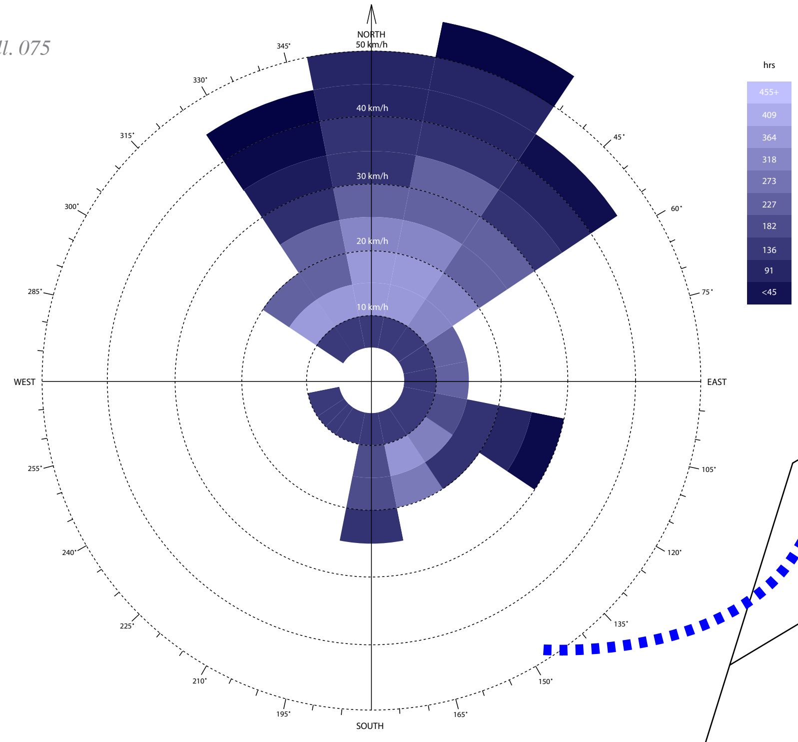
Ill. 074



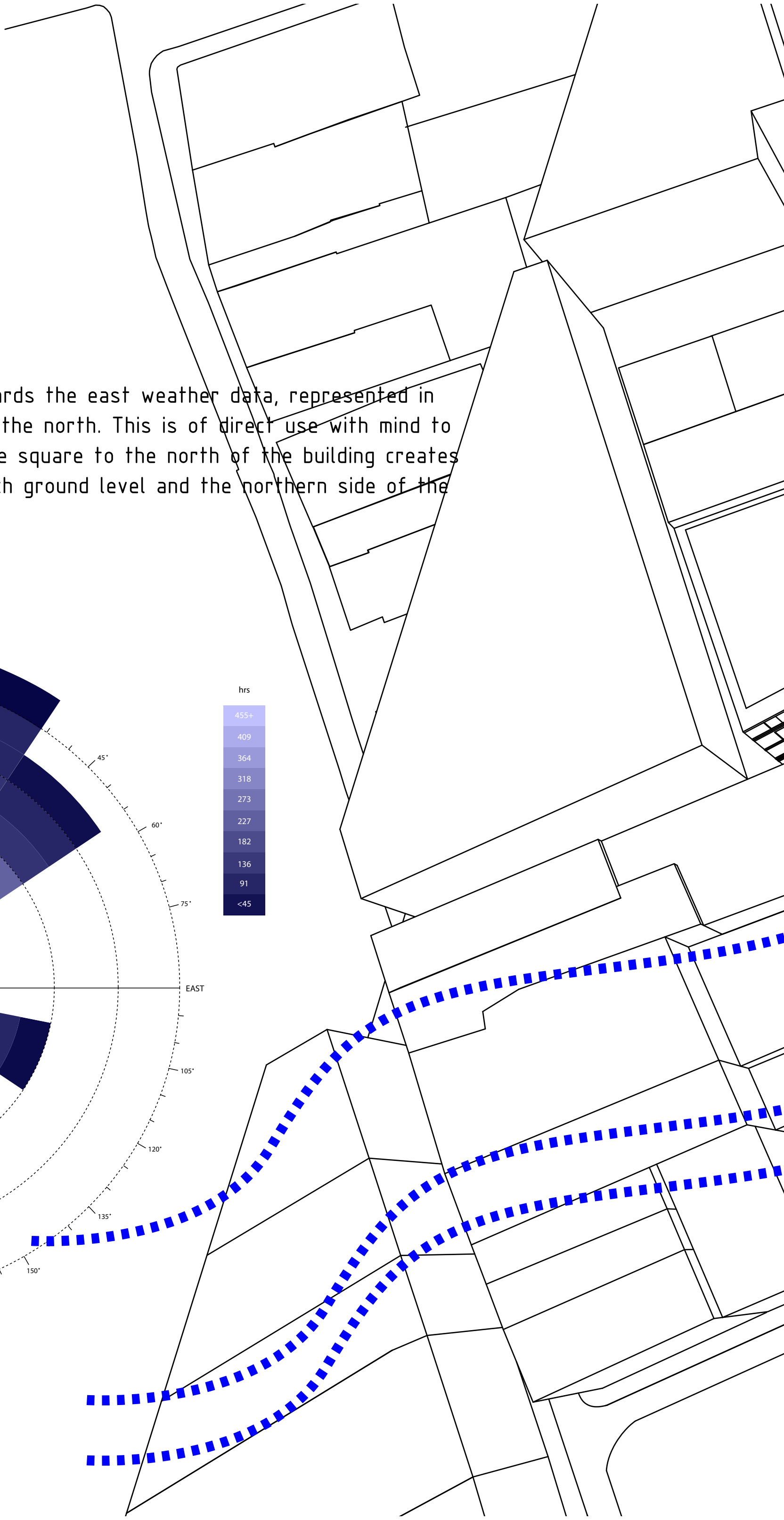
Ill. 073

Wind information

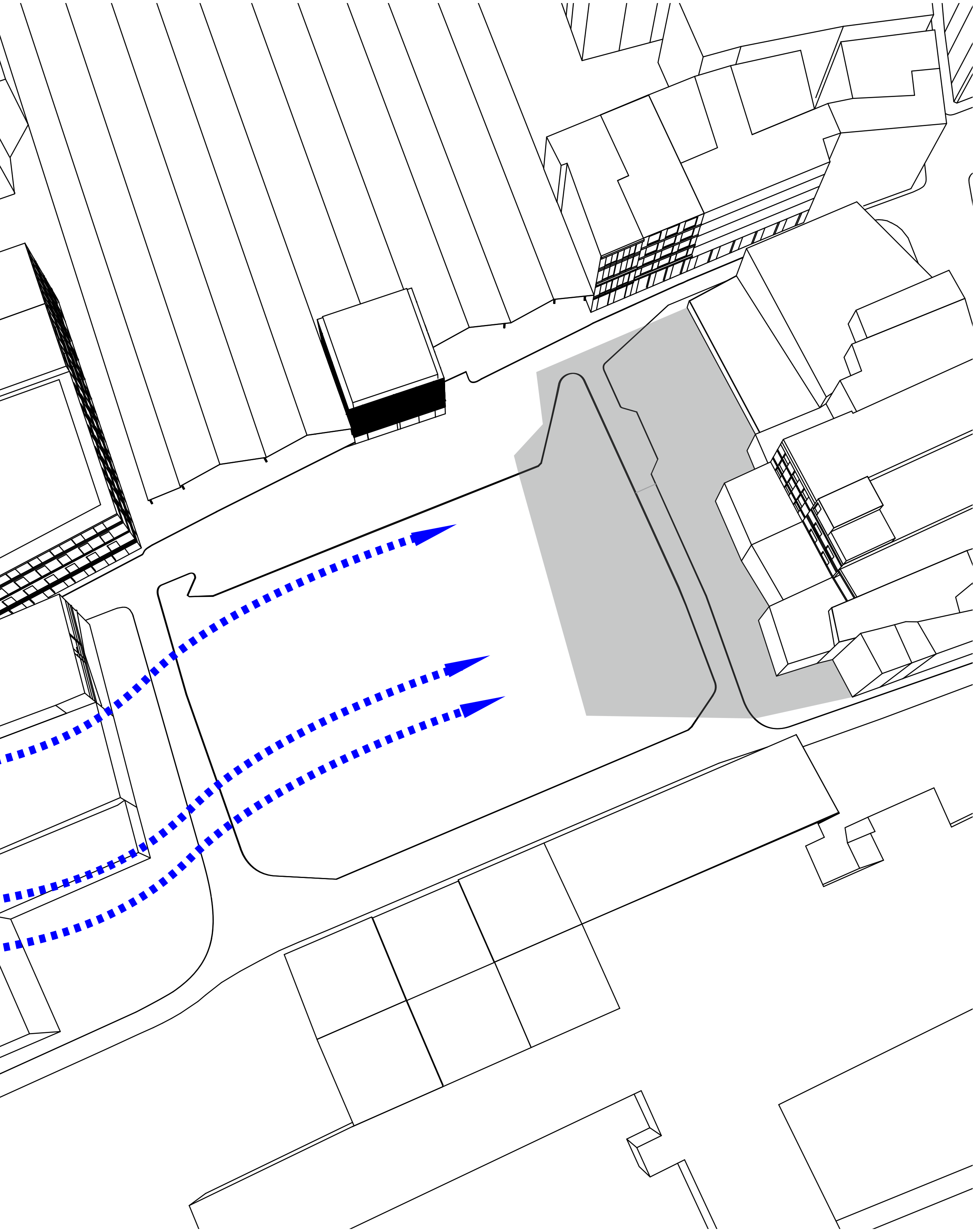
Though located with the Mediterranean Sea towards the east weather data, represented in a windrose shows a strong prevailing wind from the north. This is of direct use with mind to the Mangd illustrated earlier. The location of the square to the north of the building creates furthermore an urban void, allowing wind to reach ground level and the northern side of the building.



Ill. 075



Ill. 076



6.2.3 SPATIAL PROGRAMME

The spatial programme is created through the idea of framing traditional paper-based material and contemporary and future digital material in one singular space. Open, well-lit zones for reading complement enclosed zones for visual and audible studios, forming the main spatial programme. Functional parts such as a small depository, offices, restrooms and a cafe to further enhance the public air of the plaza have been added. The entrance is located at the ground level (level 00) with direct connection to the plaza comprising the reception and a space for small exhibitions and digital displays as well as, due to the reasons of logistics, the depository.

The main part of the programme is distributed throughout four levels according to space specific needs in terms of lighting and accessibility.

The programme is thus seen as a guide as to how to define internal spatial organisations and their specific location to each other and within the building rather than a precise metric measure of individual room sizes.

Space	area (m2)	daylight factor (%)	daylight/sunlight (diffuse/direct)	natural/artificial light (%)	location (floor)	
Entrance	350	5	diffuse	80/20	0	
News section	20	–	–	–	–	
Exhibition area	150	–	–	–	–	
Counters	80	–	–	–	–	
Café	100	–	dif./dir.	–	5	
Paper-based material	1500	5	diffuse	70/30	3-5	
Culture	xx	–	–	–		
Education	xx	–	–	–		
Foreign languages	xx	–	–	–		
Travel	xx	–	–	–		
The Arts	xx	–	–	–		
Magazines	xx	–	–	–		
Children books	xx	–	–	–		
Reading	xx	–	–	–		
Digital material	500	3	diffuse	50/50	2-3	
Visual studios	xx	–	–	–		
Audiel studios	xx	–	–	–		
Interactive studio	xx	–	–	–		
Open area	xx	–	dif./dir.	–		
Depository	300	1	diffuse	10/90	2	
Storage	200	–	–	–		
Handling/Care	50	–	–	–		
Server room	50	–	–	–		
Administration	250	4	diffuse	70/30	1+5	
Offices	xx	–	–	–		
Kitchen+relax	xx	3	dif./dir.	–		
Restrooms	xx	2	diffuse	50/50		
Services	300	2	diffuse		1-5	
Restrooms	100	–	–	30/70		
Elevators/stairs	200	–	dif./dir.	70/30		

Plot size: 600 m2
Plot height: 5 floors
Building floor area: app. 2500-3000 m2 (incl. double-height spaces)

Ill. 077

Conceptual spatial organisation

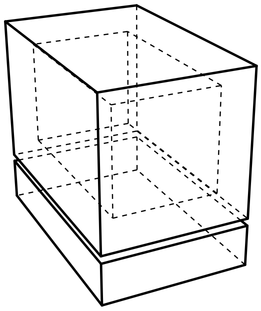
As an initial organisation of the library a conceptual organisation is created with the above listed programme. The library is divided into three major zones, 1) Entrance (reception, exhibition and depository), 2) Core (bookshelves and studios) and 3) Periphery (open study space). This ensures well-lit reading and meeting zones, as well as enclosures for spaces with physical demands of no direct sun exposure.

The second step within the conceptual organisation worked with the interpretation of the solar paths within the dense urban context effecting the east and west facades in such a way that their non-exposure to direct sunlight enabled the stretching of the core to the boundaries of the building, thus enabling a longer spatial flow of the latter and thereby allowing a greater freedom within the overall design and spatial assignment.

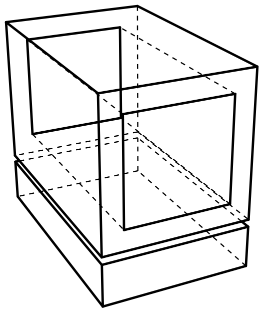
Conclusion INFORMATION

A series of data, gathering environmental, topographical and spatial elements into a project base for development is created through the INFORMATION section serving as input to computational parametric systems. Explicit data have different values and will be implemented into the pre-solutions through heuristics in hierarchies. This is to be understood as the designer reads spatial quality better than a computational system, whereas performative optimisation can be improved through computation. Material investigation, being the fourth parameter described in the 'Operations' chapter has yet not been implemented into the information base. This is seen more appropriate in the development and research of the local system within the FORMATION section.

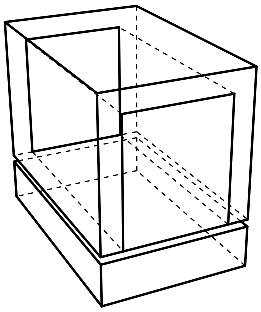
Ill. 078



Conceptual organisation of the library presented in an entrance, a core and the periphery shell.



The core is stretched to both sides enabling longer spatial flow and visual connection to the outside, exposing the core.



Core expands to connect to the entrance area, connecting all parts of the library together.

6.3 FORMATION

The following section is a research into geometrical and material systems, studying different relational organisations. It is as such an extension of the experiments done in the theoretical part with the aim of constructing 'Pre-solution' design systems, responding/reacting to the information layer studied in the INFORMATION section. Systems are created in the prior formulated organisations of systems within systems, or more precisely a global and a local system.

Two operational scales are developed, which have the potential of constant interaction with information and design wishes to accommodate a design approach from both bottom-up and top-down perspectives simultaneously. By the creation of two related, but independently organised systems, interleaving is enabled in a later form finding process as the informational systems can be provoked locally and globally.

The adaptability of the systems thus relies on variable input, to perform as a dynamic entity without changing its geometry after a form finding process. Simple, explicit pre-solution constructs are based on heuristics as described through the theory, which might seem insufficient towards complex performative organisations. As will be illustrated later, this is not the case by an aggregation of systems to performing morphology.

6.3.1 DEVELOPMENT OF GLOBAL SYSTEM

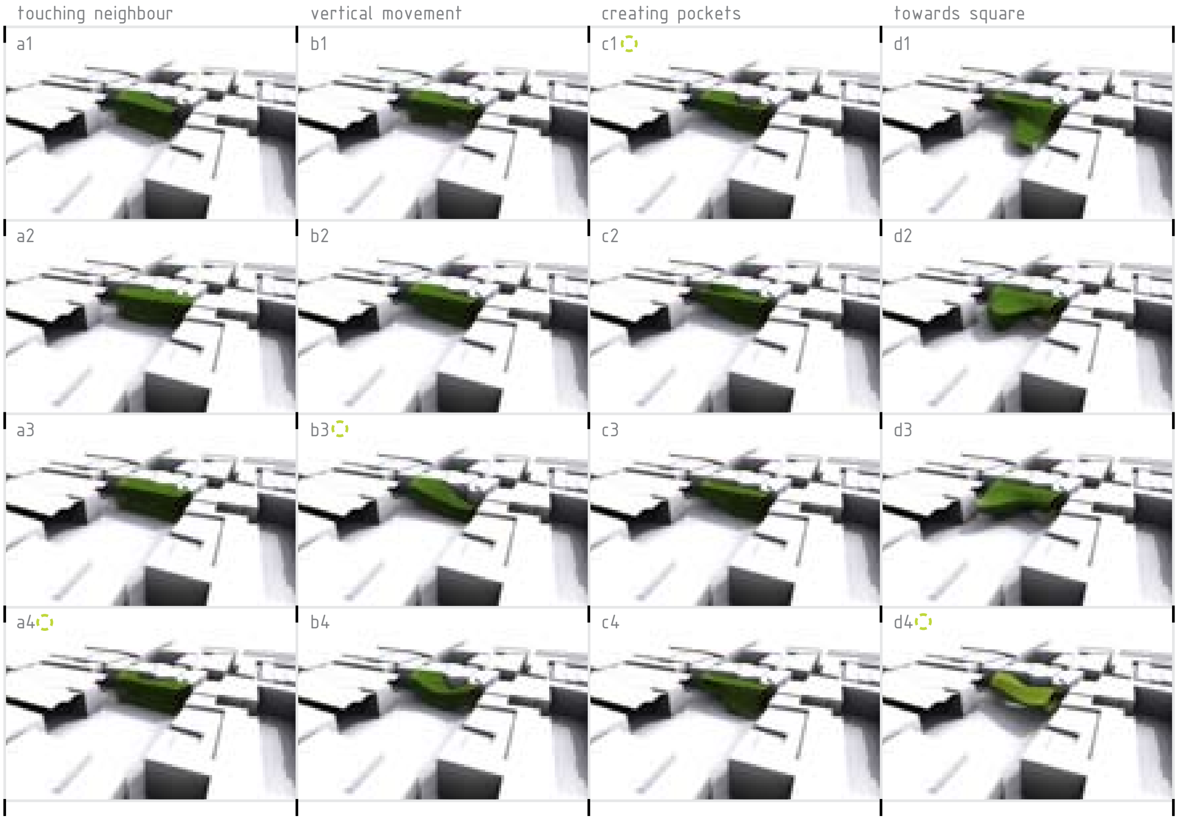
Investigation and development of a global system

To bridge the information layer into a global system, an investigation between mapping and a parametric/associative controllable system is done trough a topology study.

The strategy of the topology study is thus to investigate various relations and connections to the site, and an understanding of the solar/shade effect according to geometry. This provides an understanding of restrictions and creates a base geometry, a global adaptive system, that can then be parameterised into a 'pre-solution' capable of adaptation to parameters.

Topologies are grouped into four categories; touching, vertical movement, pockets and horizontal movement referring to their deformation action, from site conditions given by the site boundaries. Touching refers to the building body connecting to neighbouring buildings. Vertical is a deformation where the volume creates space towards the terrain or slopes downward. Pockets create folds into the envelope for spatial pockets and Horizontal movement towards the public space.

Four types of each topology are created, where the preferred is illustrated and described through the same evaluations criteria's, geometry, wind, solar and topography, relating to the parameters formulated in the theory. The final base geometry can be seen as a hybrid of topologies.



Ill. 079
Various topologies are investigated, registering different spatial formations in context, without losing the volume that can contain the chosen programme.

Vertical03

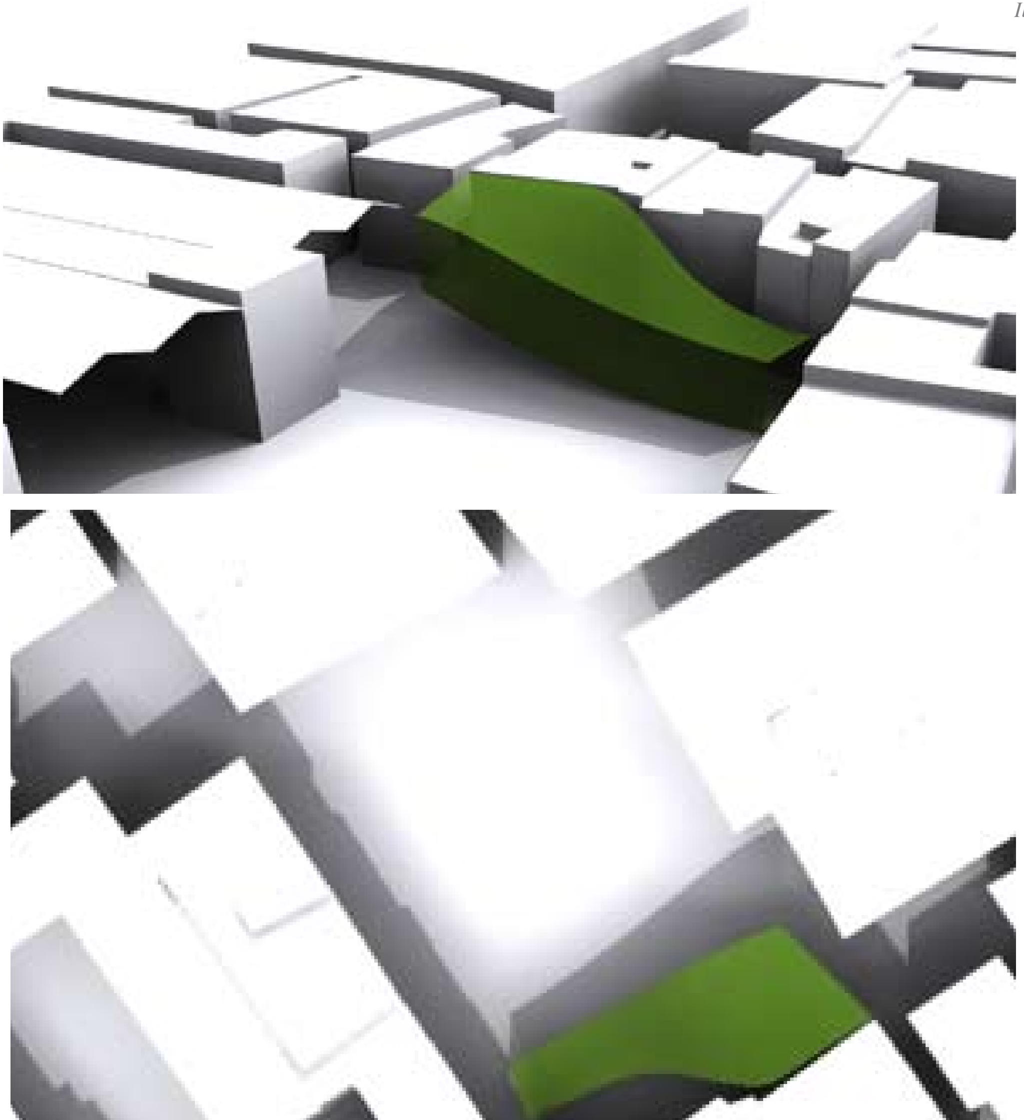
Geometry
A vertical deformation is created in both ends of the building geometry pressing the volume down and up.

Wind
The opposite end to the lowered building geometry is raised creating cross ventilation possible despite the connection to the neighbouring building in that area.

Solar
As the building volume decrease in height, solar rays have improved conditions for reaching larger areas of the building. This also improves the daylight condition in the courtyard area.

Topographical
The deformations allow an evening oriented space on the roof of the building as a social platform for the library visitors and to bring the building scale more towards the movement of the square.

Ill. 080



Touching04

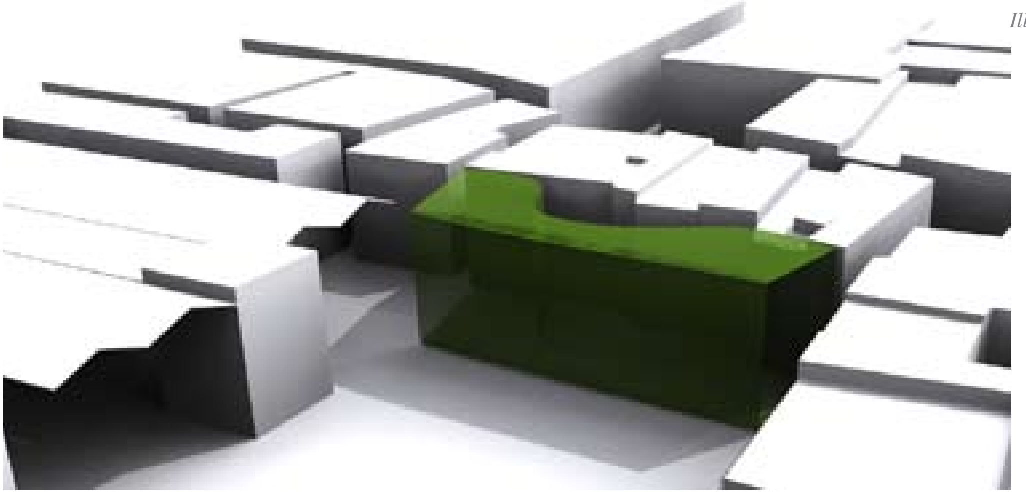
Geometry
The topology is located on the site boundaries touching the neighbouring building in two places with a gap in the centre. This allows an inner courtyard for the library visitors, but with limited space for activity.

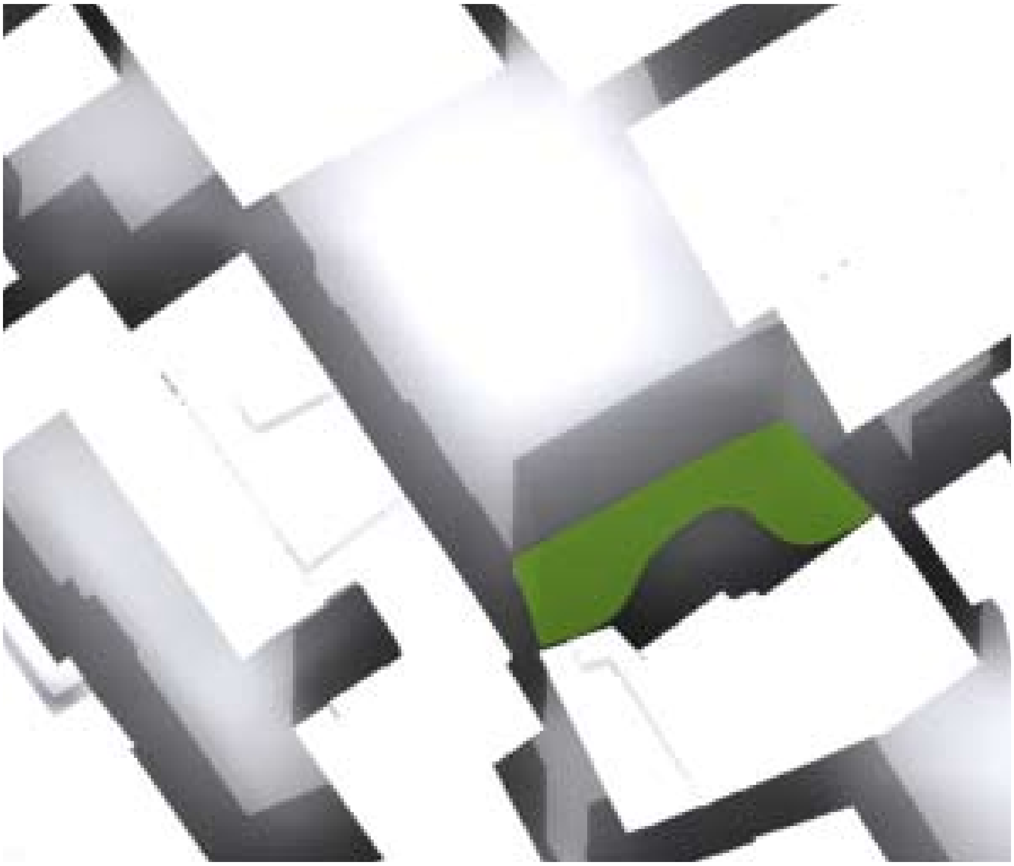
Wind
By pushing the building volume inward an opening is created for ventilation, improving cross ventilation in the centre part of the building, which thereby also becomes a possibility for the neighbouring buildings in the area

Solar
Southern sun has access to the centre part through the opening and creates a light shaft between the two buildings, improving both daylight conditions and heat gain.

Topographical
A social enclosed shaded space is created, allowing outdoor activities such as readings or exhibitions protected from lateral winds and noise.

Ill. 081





Pockets01

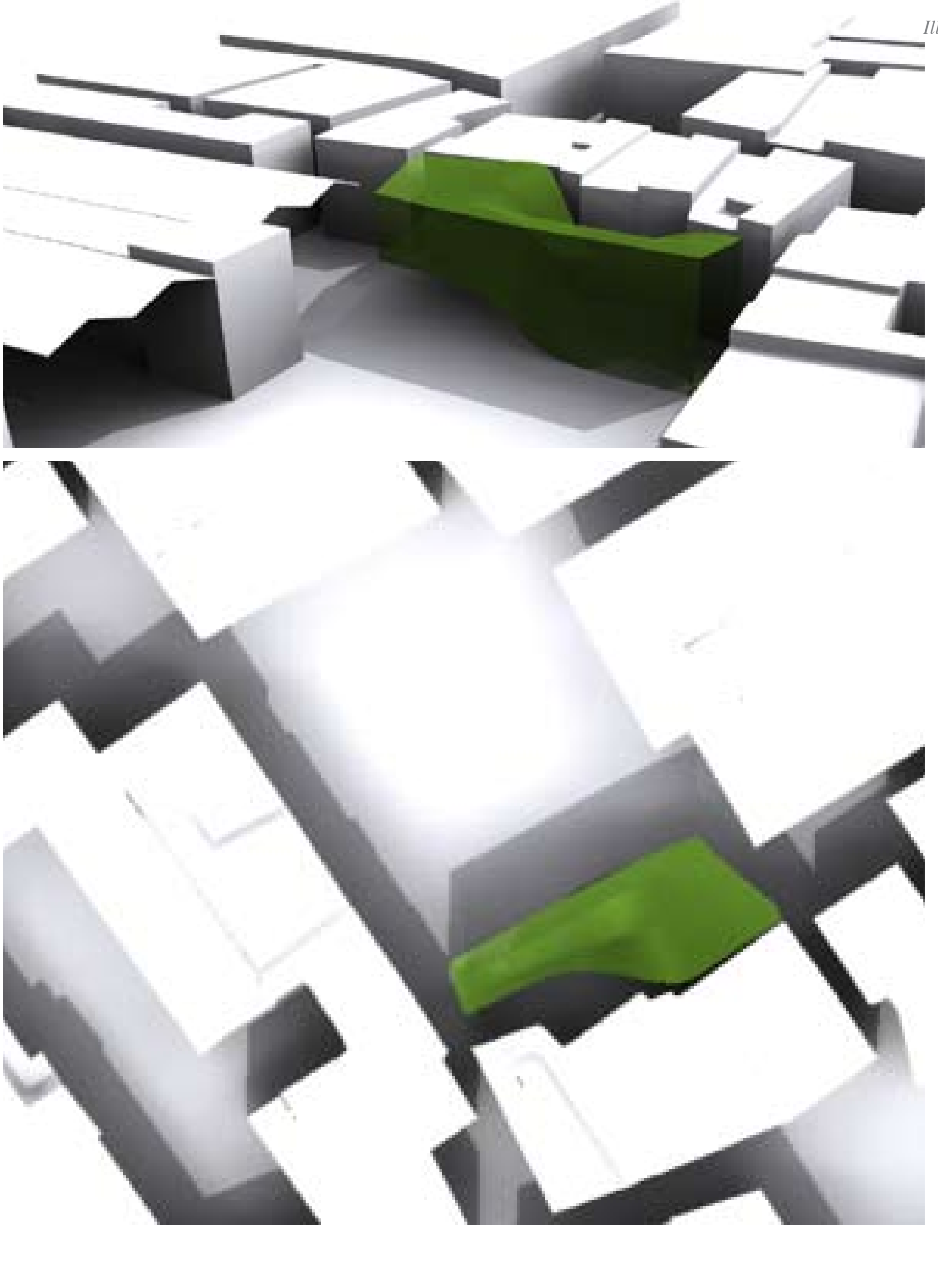
Geometry
A local deformation into the building volume creates pockets and spatial possibilites both on the inside and the outside of the building.

Wind
The pockets create a larger surface area, which allow more ventilation and from diverse orientations.

Solar
Daylight can be controlled through different orientations in local building zones, improving control of diverse internal light conditions.

Topography
Outer spatial pockets frame more intimate spaces to surrounding buildings or direct views over the old city centre.

Ill. 082



Square04

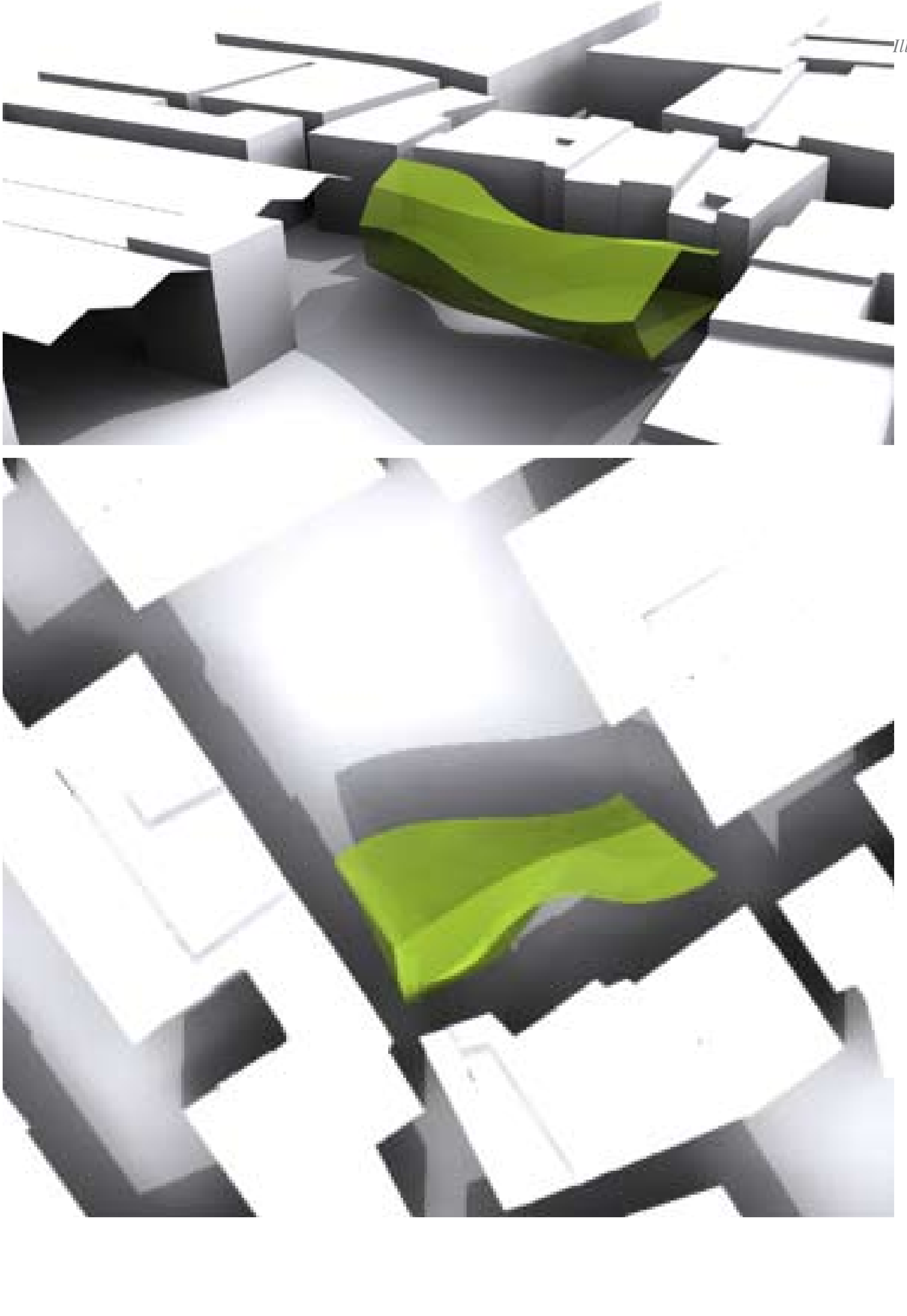
Geometry
Connecting to the square in front of the building through movement of the building volume towards north.

Wind
By moving the building towards the square liberation from the neighbouring building is possible. This improves ventilation over the entire volume, as cross ventilation becomes possible everywhere.

Solar
Morning and evening sun have also access to the area created between the building, creating a better outer zone with both shade and direct light. Furthermore daylight conditions and solar gain are improved as light can enter from all sides of the building.

Topography
A more open space is created behind the building allowing access from the square and from the two streets running next to the project site. The square and the human flow have thereby better access to the library from diverse positions, inviting the public.

The final model is a hybrid between horizontal movement, vertical movement and a partial touching of the neighbouring building. A daylight analysis is made to verify the base geometry for further development into a computational system, revealing high light levels between the neighbouring building and the library.



Ill. 083

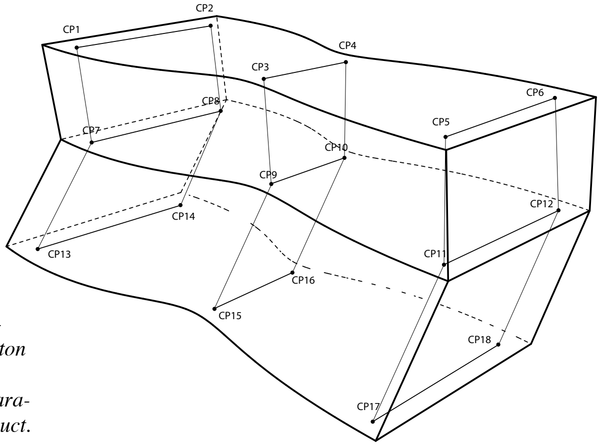
TOPOLOGY TO PARAMETRIC RELATIONS

Contouring the chosen topology as base geometry into a series of parametric controlled curvatures enables a connection from topology studies into a global performative system. Differentiation within curve densities are investigated according to programme and formation need. This enables a system that controls the global geometry with possibility for local deformations according to sustainable parameters and spatial programme.

The global system is controlled and designed by information of four strategies;

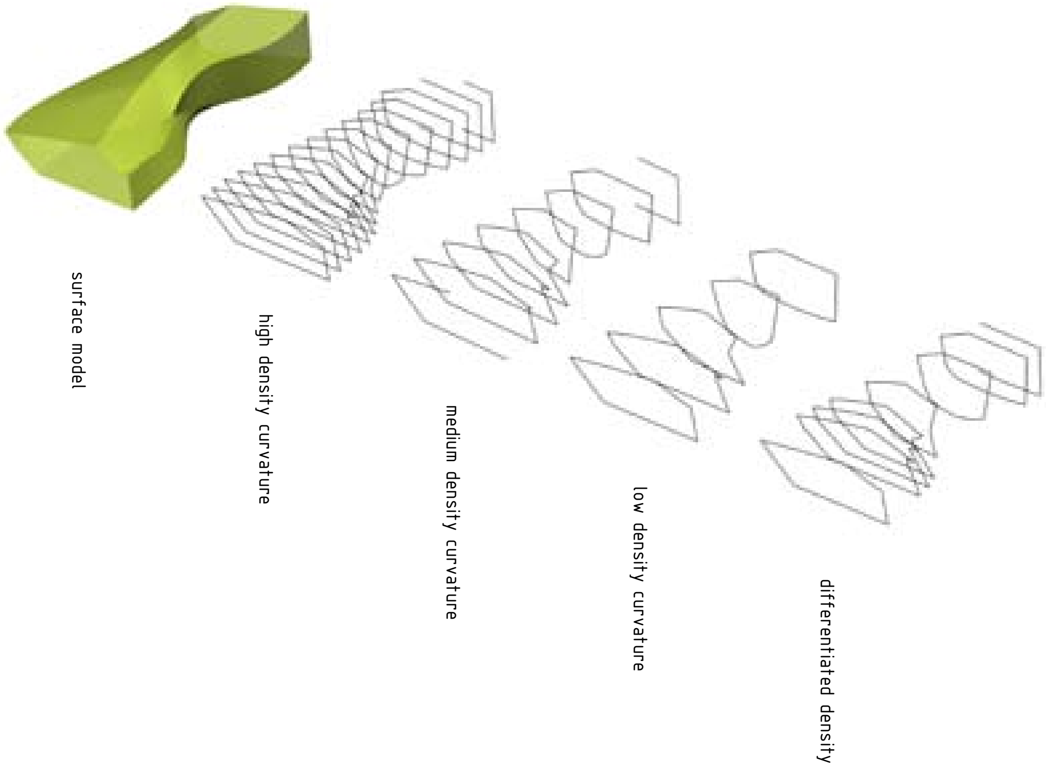
a) depth according to daylight and ventilation needs (effects indoor environments)
b) facade angle towards solar paths (effects indoor environments)
c) global shade created (effects outdoor environment)
d) negative space created (effects outdoor environment)

The global system is thereby controlled/informed manually by the designer as a respond to analysed parameters through simulations and spatial organisation in relation to programmed areas and spatial effects as proportional relations, enclosure and openness. Relating the global system to control and chaos notations show that its constructed with a majority of control by the designer, based on the four strategies listed above and the data feedback from environmental analysis.



Ill. 084
A representational geometry illustrating the skeleton movement of the global system responds to the parametric/associative construct.

Ill. 085


surface model
high density curvature
medium density curvature
low density curvature
differentiated density

6.3.2 DEVELOPMENT OF LOCAL SYSTEM

The experiments from the theoretical part together with the Paris Media Centre by Arup, illustrates different local systems reacting as geometrical systems (experiments) or material systems (Paris Media Centre). In the search and development of more profound adaptive systems, a look towards nature provide for a rich catalogue of strategies in both geometrical and material relations. Studying mechanism and behaviours as described among others by Weinstock leads to properties of adaptation to environment.

Matter being content as described in theory with adaptable properties is instrumentalised through geometrical relations within the parametric constellations, constructing the respond system (local system) and through material properties of structural strength, light reflectivity and absorption of solar energy.

A biomimetic study is through these ideas implemented to evolve solutions beyond immediate sustainable concepts, which provides a base for development of the local systems.

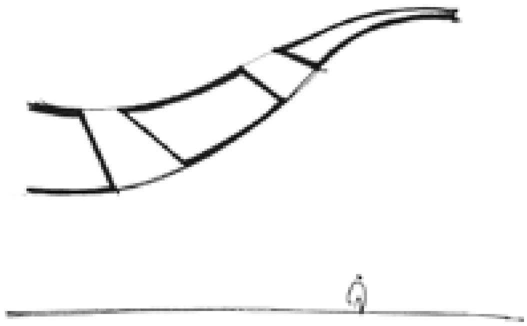
Biomimetic study
Four elements of investigation are illustrated with the above-mentioned aim. Being true to the source of investigation requires a dismantling of the project restrictions as for instance spatial programme to not limit the potentials of the element.

Each element is described in three stages, information (what is it), strategy (how can it be used) and application (implemented into an architectural element). The aim of the study is not to create a local system, but to create a research base (as the topology study provided a base for the global system), to which a local system can be designed with the library in mind.

Ill. 086 *Three natural investigated elements used for a biomimetic study of systems and behaviours. From left, almond shell, snail shell and a maple seed.*

Ill. 087

Inside of almond shell

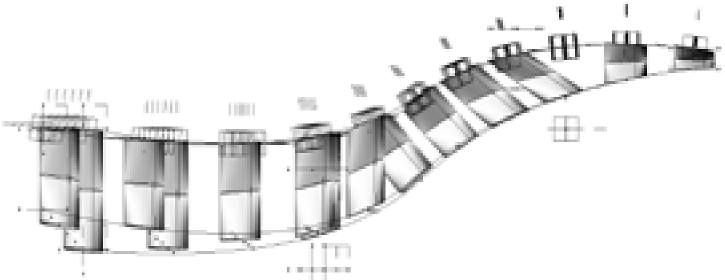


Conceptual system

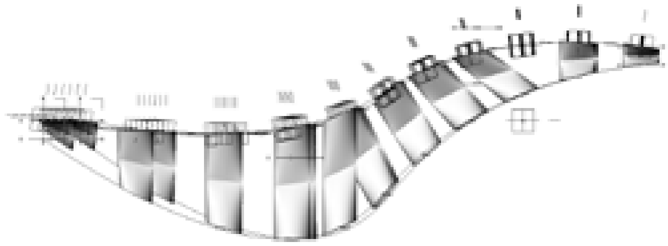
The almond shell is constructed of contrasting surfaces from the rough outside to the smooth inside framing a natural developed structural and breathing system, which regulates its interior conditions through distancing the two layers.

Focus of the system is placed into the behavioural mechanism of controlling moisture, nutrients and light into the core, to which an adaptable double skin, with diverse depth is developed. This controls the tubular openings and enables/disables light and air to penetrate the global surface system according to temperature and daylight desires. The envelope is thus organised from environmental parameters in a continuous surface geometry.

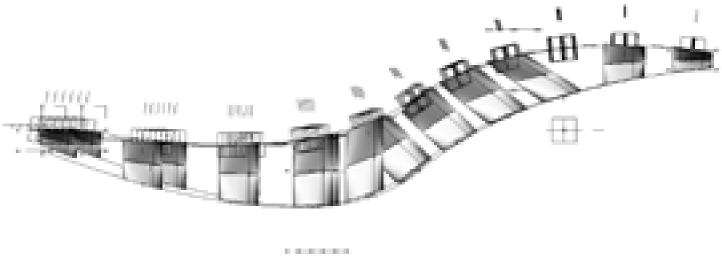
Applied system



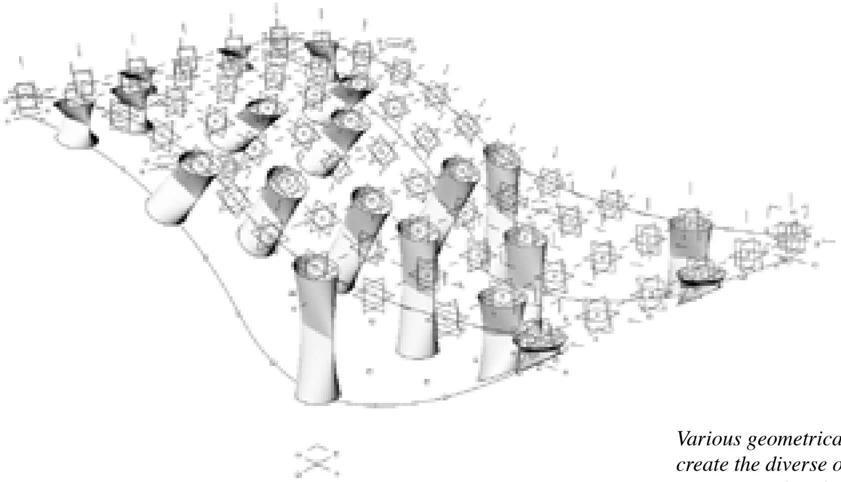
Modulation 01



Modulation 02



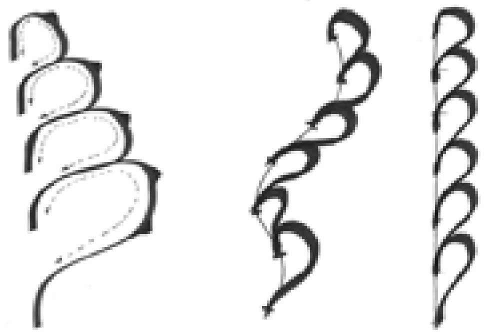
Modulation 03



Various geometrical relations create the diverse openings across a surface by differentiating the distance between inner and outer layer.

Ill. 088

Inside and outside of snail shell

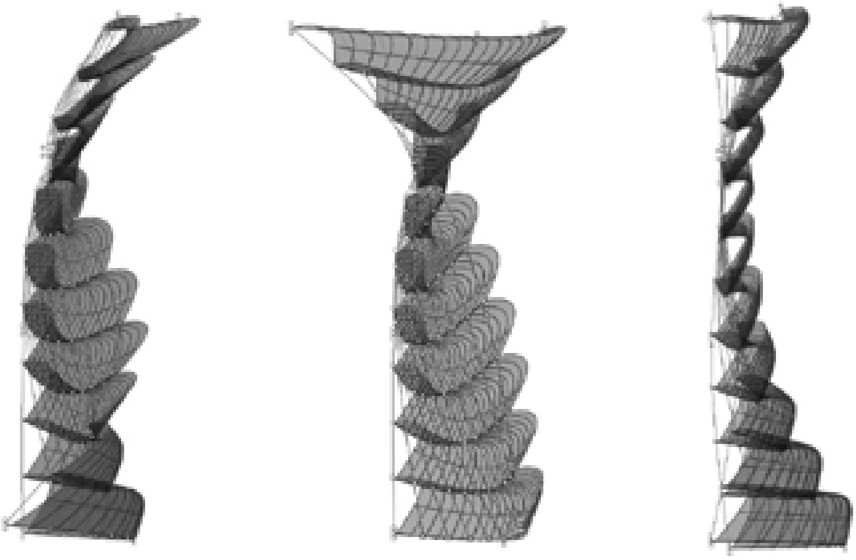


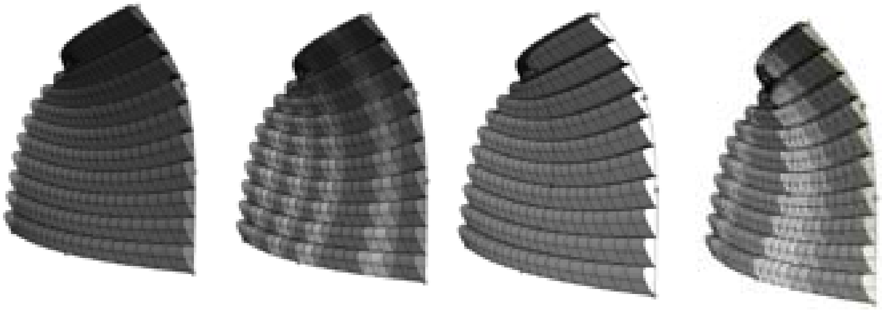
Conceptual system

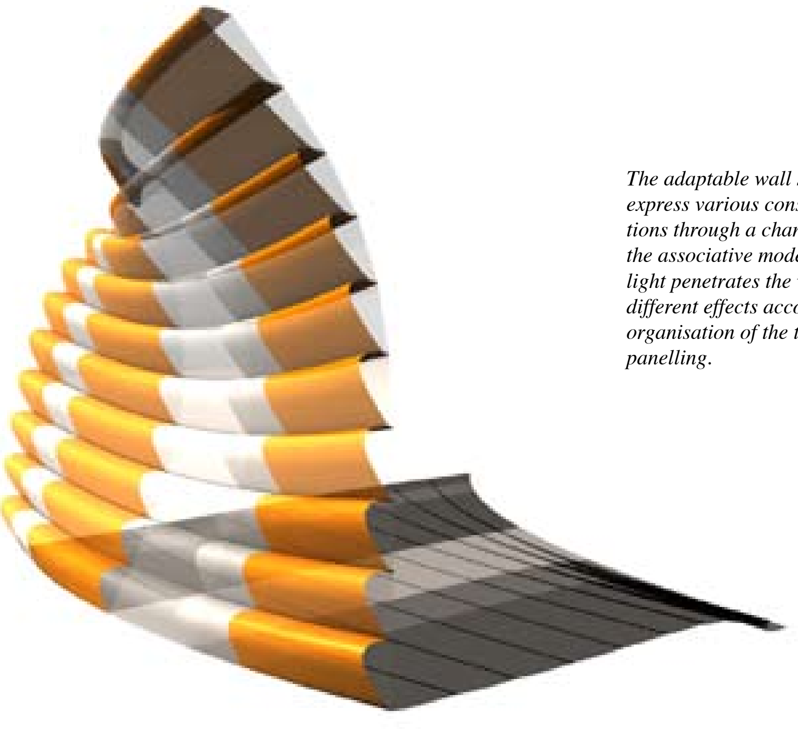
The sea snail illustrates structural absorption through leading the force flow towards a flexible core, which allow bending to avoid breaking. This is done via force lines in arches and curvature constructions in load lines. Where forces seems to be able to brake the flow, material is added to strengthen weak parts through the spikes.

Various translucence gradients can be detected in the sea snail shell, which are transformed into a highly programmatic panelling with the aim of optimising solar penetration. The bending chambers are further seen possible to transform into thermal pockets improving insulation values, when applied to the structural absorption system.

Applied system

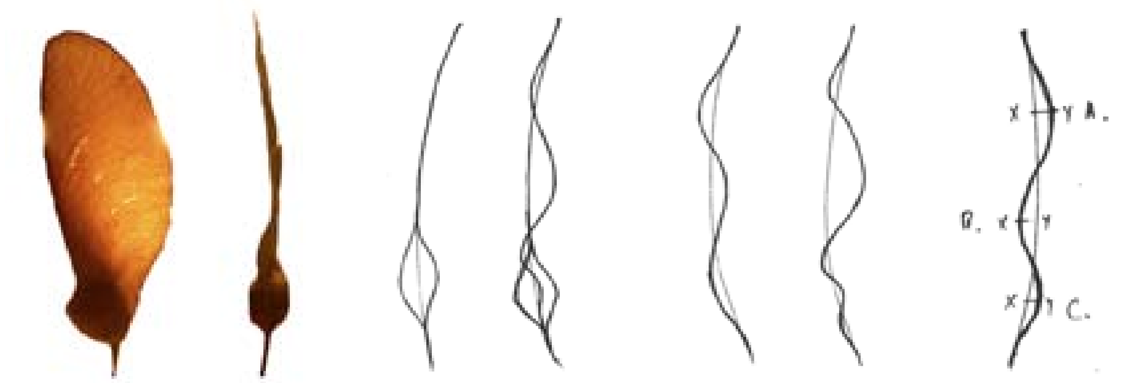






The adaptable wall system express various constellations through a change in the associative model, while light penetrates the wall with different effects according to organisation of the thermal panelling.

Ill. 089

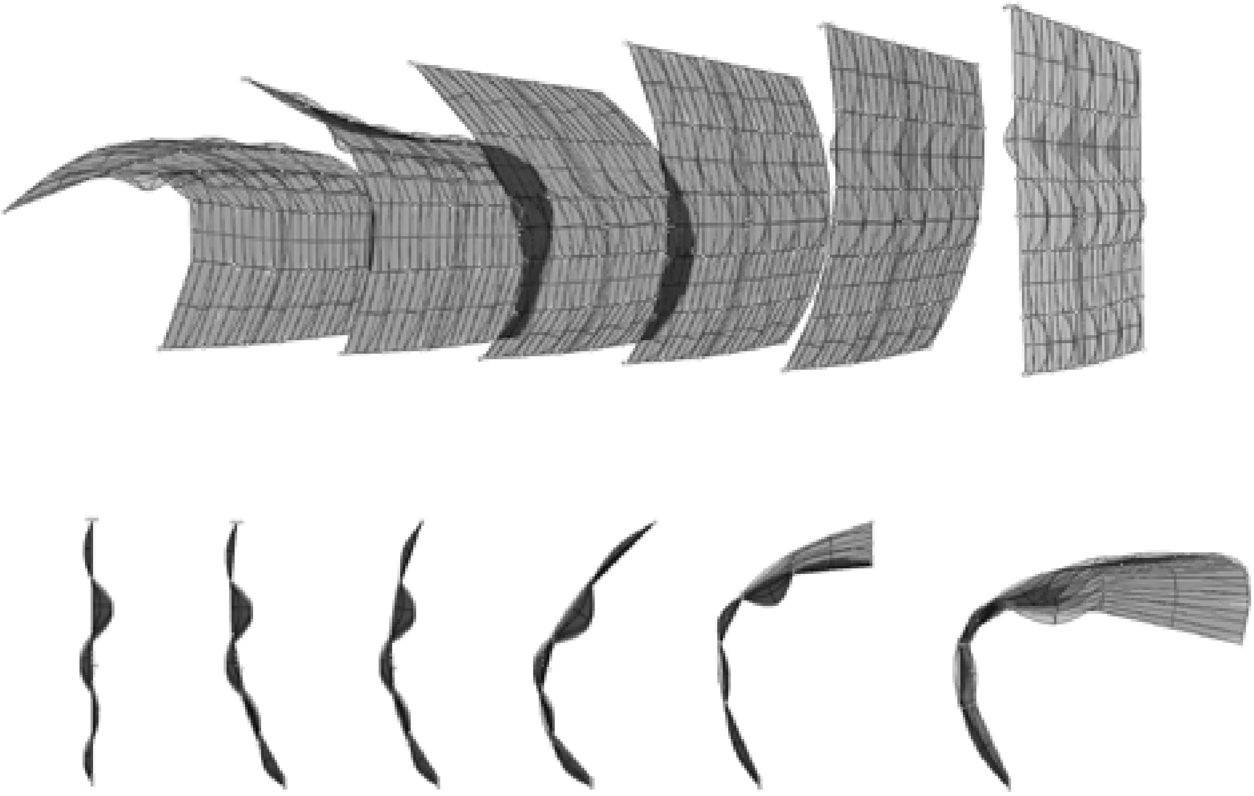


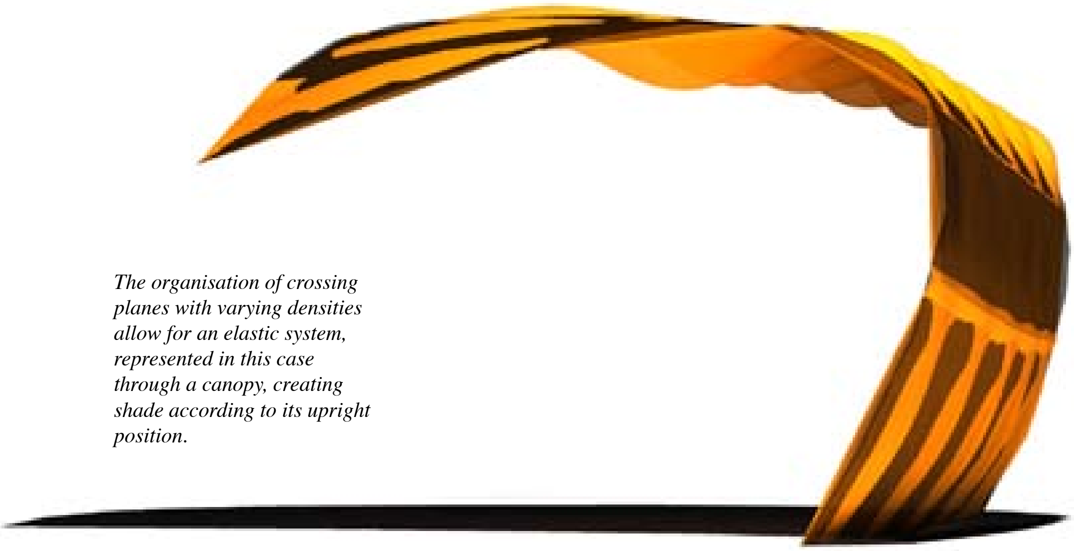
Maple seed from side and profile *Conceptual system* *Mathematical system*

The bending profile recognised in the profile of the maple seed is an effective absorber, combined with the waving flow of the wing, together creating a system with local differentiation in structural capacity through their crossing lines organised as being dense in heavy locations of the seed and vice versa.

Usage of differentiation is combined with concepts of the snail shell as a structural envelope with thermal properties through insulation pockets, shaped by the curving structural components. The derived form and system is a self-organised envelope, responding to load bearing conditions, shading and insulation optimisation.

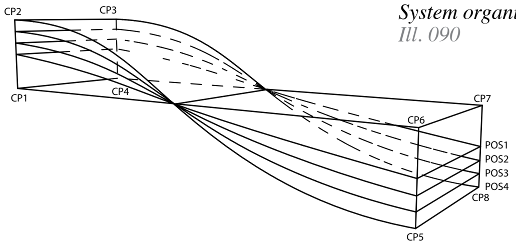
Applied system





The organisation of crossing planes with varying densities allow for an elastic system, represented in this case through a canopy, creating shade according to its upright position.

LOCAL SYSTEM 01



System organisation
Ill. 090

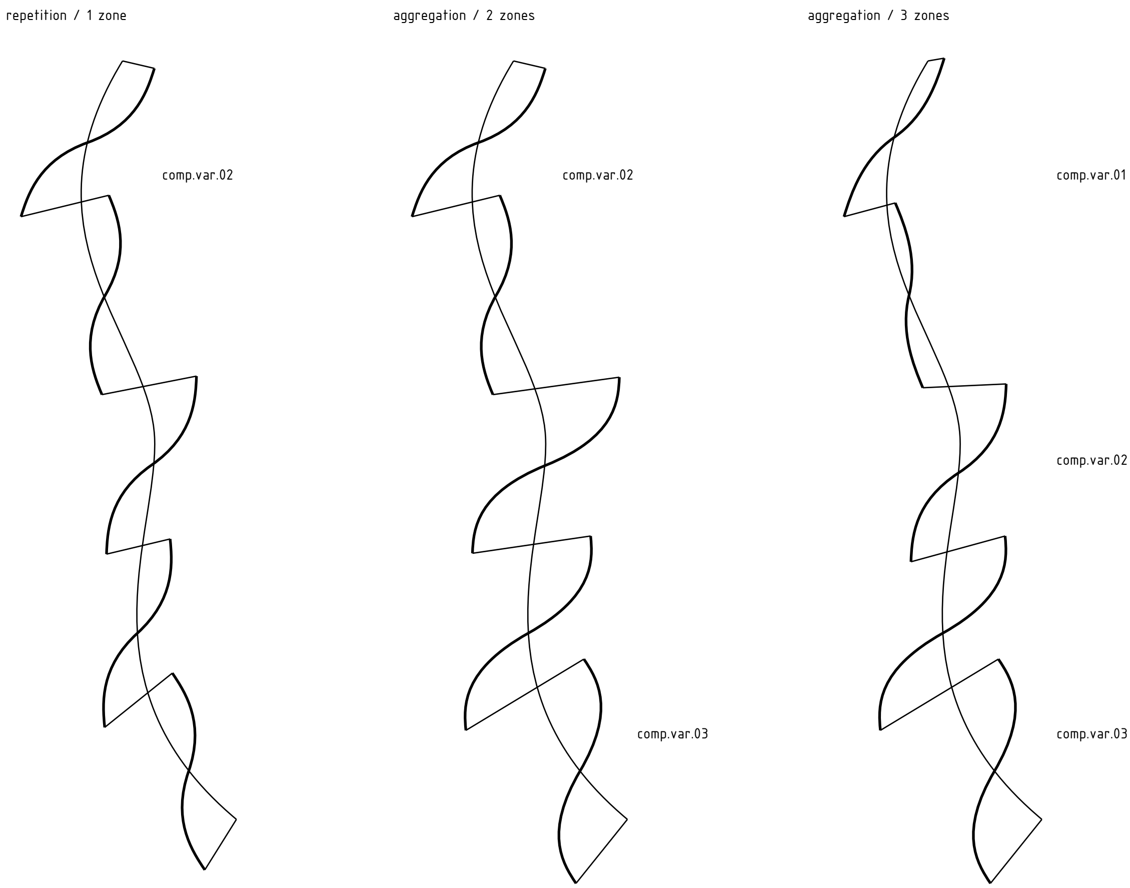
System organisation
The system is created through a simple organisation of a curve and a straight line intersected and extruded. Differences in distance between the endpoints determine the size of the local system, which react locally to information on the global system.

Sustainable strategies
Thermal pockets derived from the study of the Pleuroploca, contains the dominant sustainable strategy. Insulation values are hence adapting as a relation to the configuration of the system organisation informed locally. The system functions furthermore as a wind catcher (as described in 'Operations' strategies for wind), which can be equally adapting to location on the global system.
According to material system, solar absorption, through increased surface area, can be optimized as well as reflectance into the building, ill. xx. The system expands the surface area with 26% compared to a flat surface for higher energy collection.

Aggregation of system
Populating a curve with the system, will, according to parametric input, give different expressions. System boundaries can be controlled so that different systems (same design, different values) are located in different areas, to optimise zones (as investigated in experiment 3).

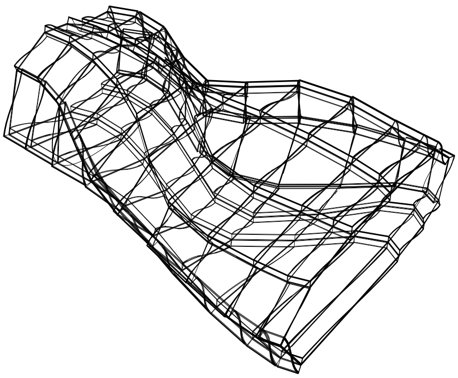
Applied to global system
Three orientations are applied to the global system for different visual effect and performance goals. To perform most efficiently, an orientation towards north is preferred to catch the northern wind and to create a larger curvature towards the south for solar energy collection.

Structural system01
Considerations towards a structural system are done with thoughts to adapting to the sustainable system through a cross bar structural system (ill.095). A structural envelope is created touching the ground in two locations (as a consequence of the topology study) creating a passage underneath the building from the area between the library and the existing building to the square.

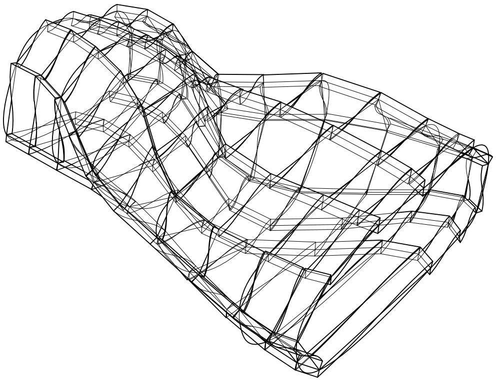


Ill. 091
System aggregation

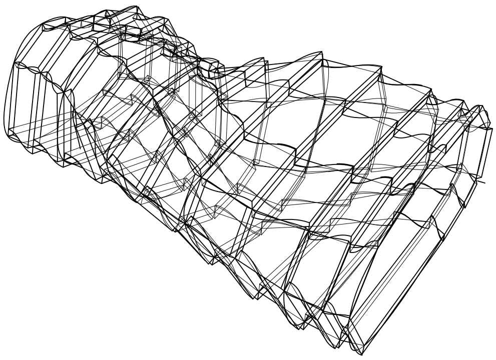
Ill. 092
South orientation



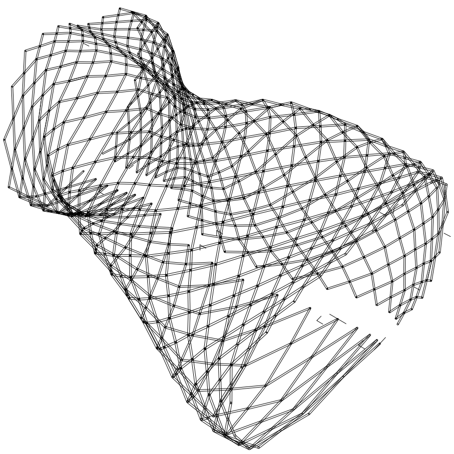
Ill. 093
North orientation



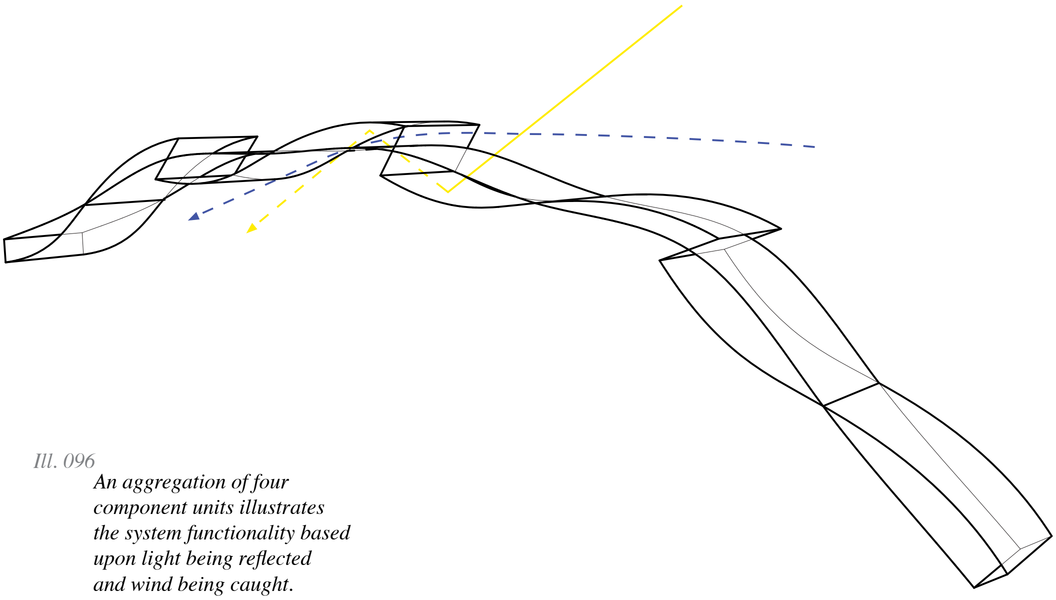
Ill. 094
West orientation



Ill. 095
Structural system 01



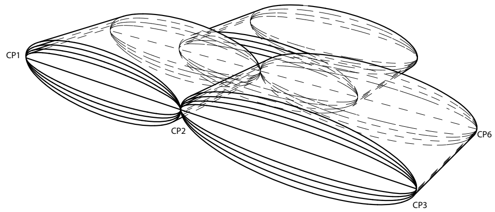
Sustainable strategy



Ill. 096

An aggregation of four component units illustrates the system functionality based upon light being reflected and wind being caught. Distance control between the curving line and the straight line adjusts the geometrical composition, enlarging or contracting the pockets.

LOCAL SYSTEM 02



System organisation
Ill. 097

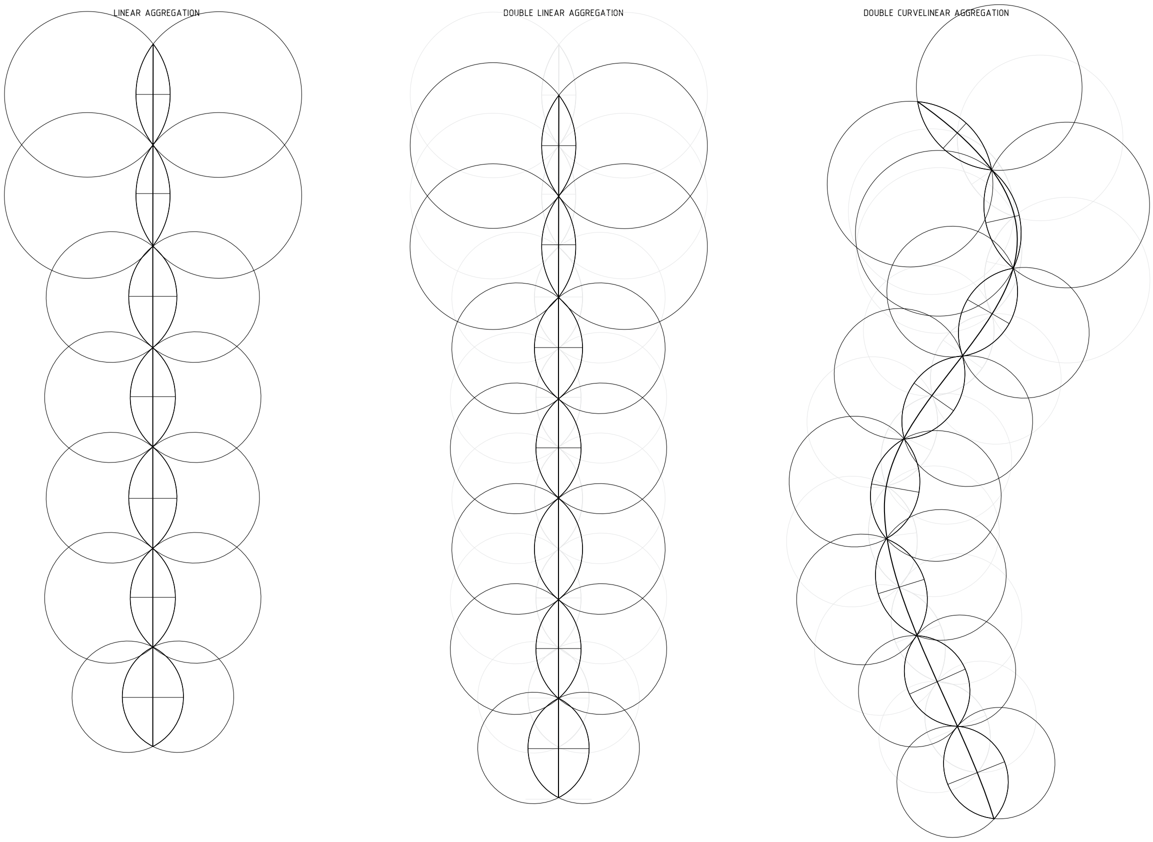
System organisation
With the aim of creating a more homogenous system, local system02 is developed with differentiation between neighbouring local component to achieve the same performance features as local system01. Circles with differentiated diameter and location determines the size and opening system in relation to the neighboring component (ill. 097). A continuous organisation creates the weaving system.

Sustainable strategies
Thermal pockets are as local system01 designed to differentiate according to local insulation requirements within the global system. Whereas the local system01 was designed to catch wind through the system, local system02 is designed to catch wind in collaboration with the neighbouring component. The system expands the surface area with 12% compared to a flat surface for higher energy collection.

Aggregation of system
Circles as geometrical drivers for defining the surface create smooth adaptation to curvilinear aggregations as illustrated and can be organised with local respond through the parametric organisation of diameter change. The system is populated onto a curvature similar to local system01.

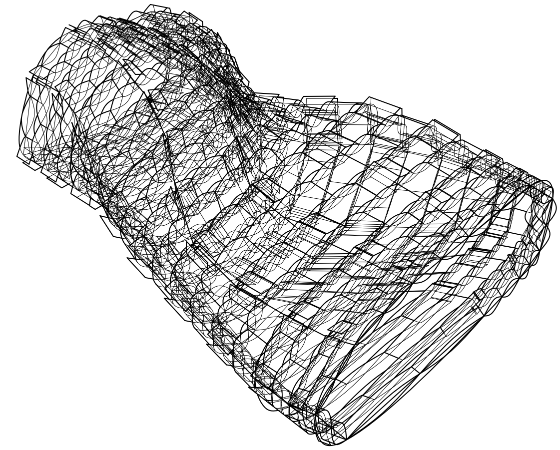
Applied to global system
The system is bi-directional (local system01 was 1-directional) meaning that the system works in two directions in one position. For this reason it enables intake of air from the south as well. It is therefore shown in two positions, enabling both north and south intake or east and west intake of air. Most beneficial is the north-south axis according to wind data.

Structural system02
The more homogenous local system is contradicted in a differentiated structural system, based upon the cross system. Through the differentiation is material use improved, for sustainable reasons and to create as light a structure as possible (ill.101).

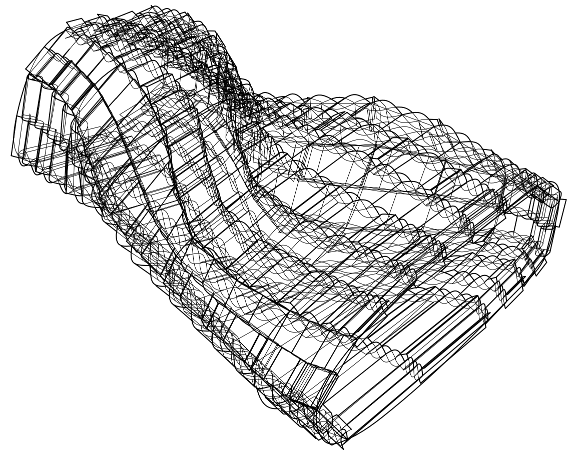


Ill. 098
System aggregation

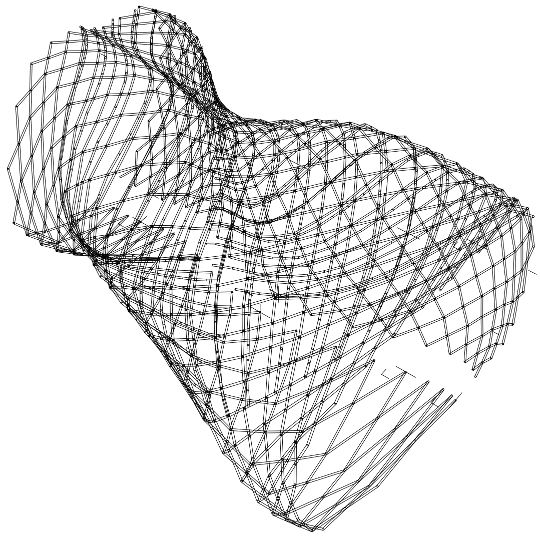
Ill. 099
East/West orientation



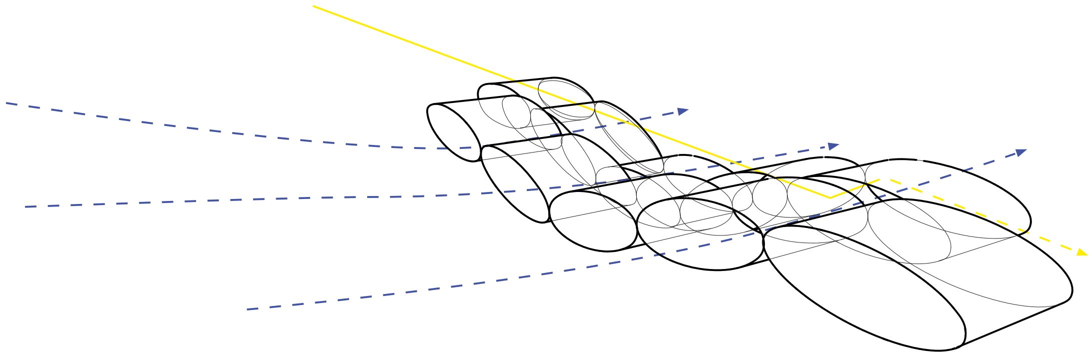
Ill. 100
North/South orientation



Ill. 101
Structural system 02



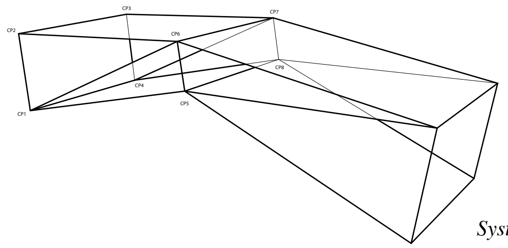
Sustainable strategy



Ill. 102

Varying densities, through diameter parameters, adjust the porosity of the system, being a construct dependent on the neighbouring component to define reflection of light and capturing of wind. As the system is designed with a high density of pockets, a high number of control points are present to which the system can respond in very local areas of the surface

LOCAL SYSTEM 03



System organisation
Ill. 103

Sustainable strategies and structural system
Keeping the homogeneous system from system02, but simplifying into straight elements, without loosing design freedom, a new system is developed through a simple organisation of a deformable cube with a single cross plane. The individual element of the cube define the systems geometrical performative characteristics in structural strength, wall thickness and porosity through its size and distance of actuating members connecting the inner plane of the system with the outer plane together with the cross plane. The sustainable system is based upon the research study of the almond shells through its ability to create various porosities by changing layer distance to improve internal thermal conditions, where as the structural system differentiation is discovered through absorbing elements detected in both the snail shell and the maple seed.

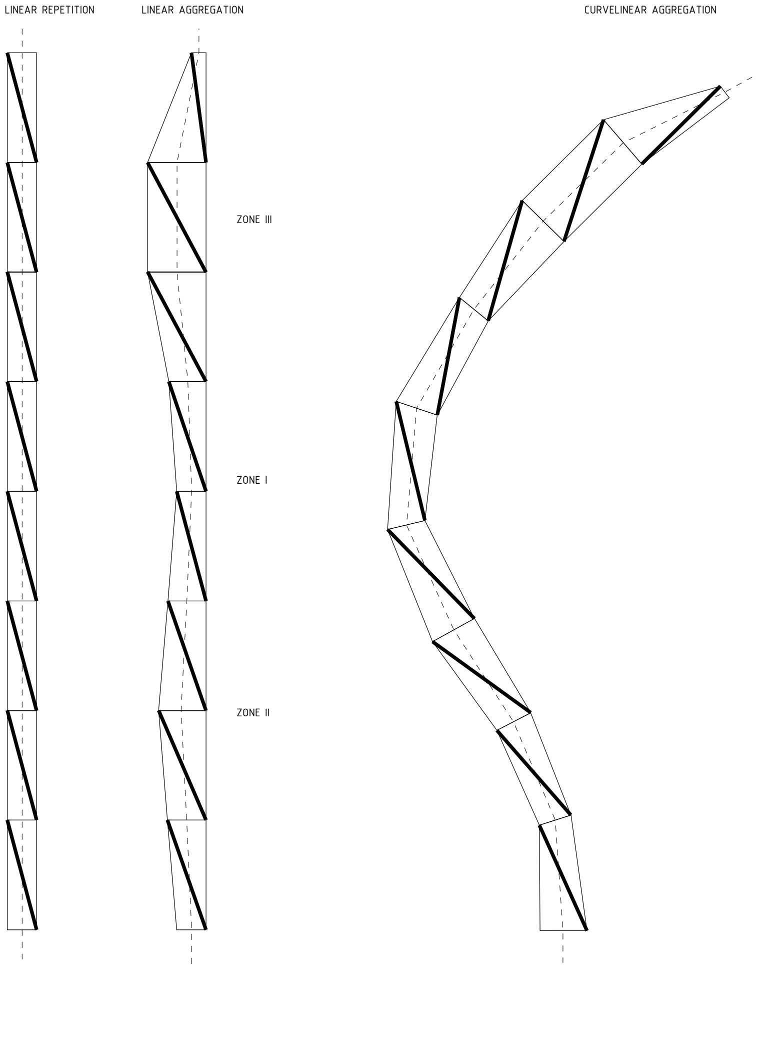
Thermal pockets are kept but opened to the neighbouring components, achieving heat accumulation for creating pre-warmed air for natural ventilation. In summer periods the ventilation system is bringing the northern wind through the system and into the atria and internal spaces, before leaving the building through the roof.

A material system is implemented via a membrane covering the inner and outer plane for its multiple performative properties, being deformable in all directions, endless shade differentiation, high insulation values, low weight, high weather durance and an environmentally friendly production process.

Straight members of the cube in collaboration with the membrane create the total integrated structural system, as the membrane functions as continuous tension member in all directions. This implies that both convex and concave curvature created from the global modulation, with following force flow, is obtained in either the inner membrane or the outer.

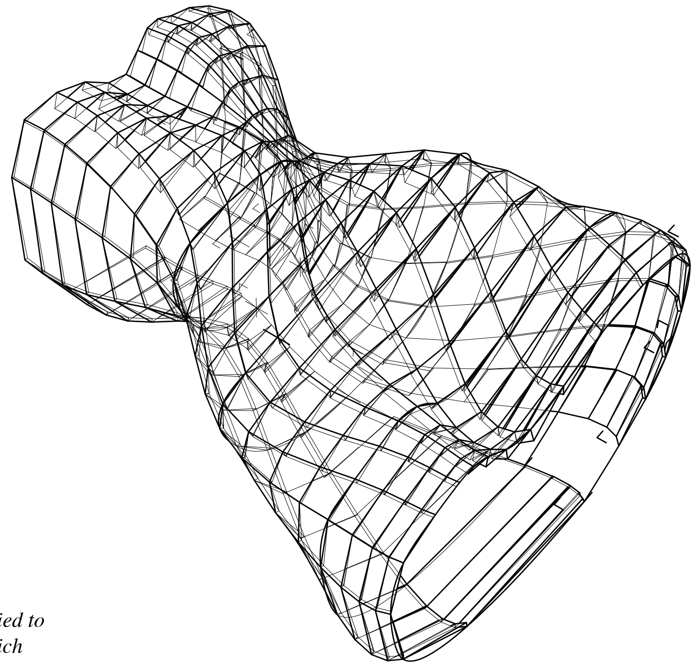
Aggregation of system
A differentiated informed system is driven by simple rules, altering the component to local adaptation. Though being designed with straight elements curvilinear expressions are possible to perform a gradient geometrical interchange with global system alterations.

Applied to global system
The local system design is applied to perform with the changing weather conditions over the course of the year, by being directed to catch the northern wind during the summer for natural ventilation, exploiting the square as space for cooling the air before entering the building, and leaving the building through the roof, creating thermal buoyancy due to the vertical flow and higher wind speeds at 20 meters altitude. Change of solar paths is used through the differentiated aperture of the system, allowing direct sunlight through the building envelope during winter and reflected sunlight during summer.



Ill. 104
System aggregation

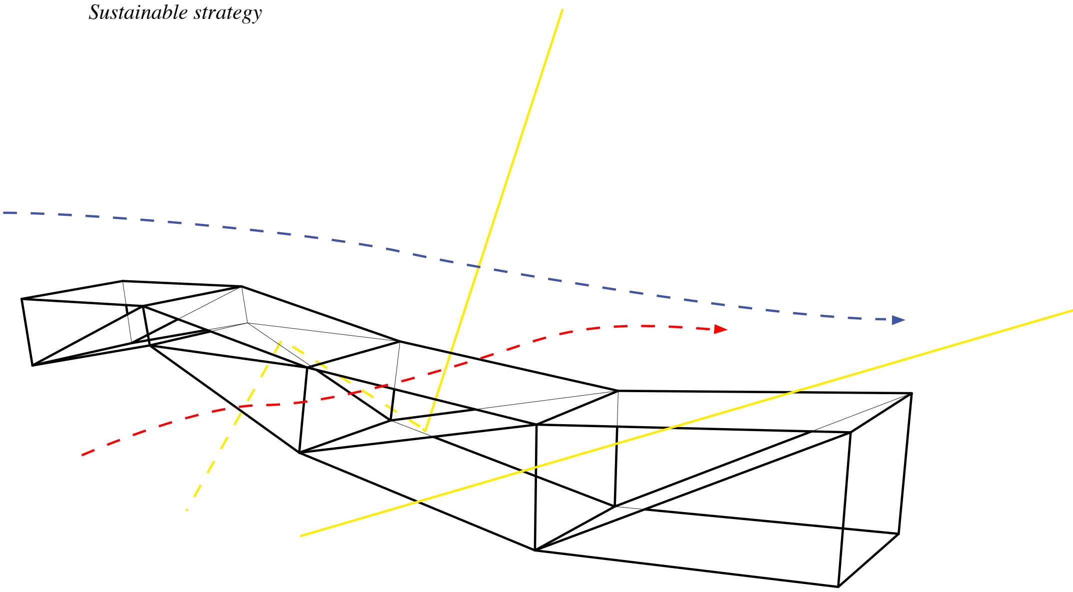
Combined systems



Ill. 105

The local system is applied to the global geometry, which gives indications of scale, number of populated local components, trouble areas in relation to self-intersecting geometries etc. The combined systems are thus a parameterised, pre-design.

Sustainable strategy



Ill. 106

Four units elucidate the system functionality designed to incorporate the weather dynamics over the course of the year, adaptable to internal programme needs of light levels, solar exposure and catching of the northern wind.

Pre-Solution Conclusions

Local systems have been developed upon the research of the theoretical experiments in parametric organisation to geometrical and material systems from the biomimetic study. The latter local system created enables several sustainable and structural properties, characterising an adaptable system responding to the project base INFORMATION. The parametric organisation and imbedded values are relative to the point of application, meaning an alteration of variables must be done after simulation feedback, to optimise the adaptable system.

The same procedure applies for the global system, being an interchange between a computational generated design and directed visual and functional expressions by the designer. The associative system responds thus to information relating to environmental data, contextual flow and architectonic judgement of the created outcome, based on local and global systems in coherence.

6.3 FORM

The following chapter, FORM, is a form finding process based upon the pre-solution systems, reacting to geometrical change from environmental analysis feedback and design wishes. The phase is organised with focus to natural daylight performance and expression as well as collection of energy, in order to create, rather than to use use and to also stabilise internal temperatures via thermal mass strategies described through solar strategies in the operations chapter.

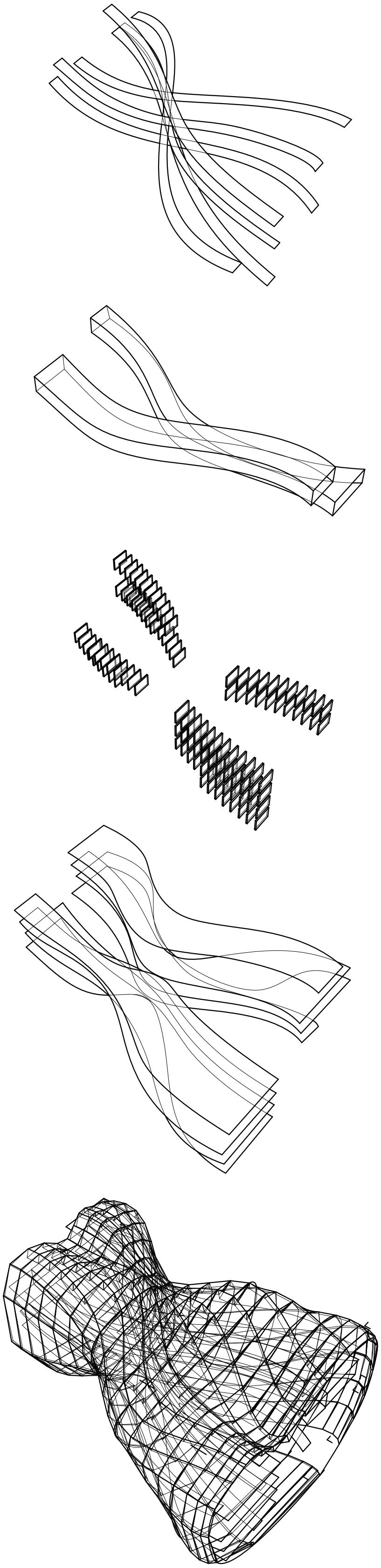
Internal and external spatial organisation is linked directly to the global formation performed through the design iterations, Design I, Design II and Design III, which are successive design modulations. Further development of Design I based on responds from environmental simulations and contextual relations (composed by local system3, global system and internal organisation) are seen essential to take advantage of the associative, adaptable system for an improved computational sustainable architecture.

The procedural methodology enables freedom with automatic optimisation to environmental aspects in a model possible to reconfigure according to information alteration through interleaving with explicit data, linking into the last design part of the process scheme suggested, based on analysis, evaluation and synthesis through computational processes described at page 47. The following chapter is thus an interchange between generating, designing, analysing and synthesising the design in an open structure. In an understanding of the procedural path a rigorous design progression is illustrated through the three design models, to finally display the library as a pilot project to the theories put forth in the first part of this work.

DESIGN I

First design proposal is composed directly from the local system3 and the global host system. A weaving envelope is the result, which inspires an internal spatial organisation, into a lighter spatial flow arranged as a chromosome structure with a centre node. The splitting plan is correspondingly derived from daylight principles of a height to depth ratio of 1:2 to allow for daylight to enter all areas. This creates two atria spaces for internal visual communication, improved cross ventilation and high open spaces with exhibition potentials.

Enhancing the two axis of the building, constructed by the envelope movement north-south and the space it frames stretching east-west, by extending flow paths and enclosed spaces an internal organic organisation of open and enclosed zones develop with diverse environments for reading, searching and meeting. The building becomes part of a greater whole representing a continuity of movement and change. Thermal mass is located in the top, south part of the building, which informs the parametric construct to change aperture, exposing the mass during winter. The remaining internal mass and bookshelves are located according to the conceptual organisation of the building; entrance, core and shell areas.



Ill. 107

Visitor movement

Studios

Bookshelves

Open reading, study, meeting

Structure and membrane added

Daylight study/Design I

A study of interior light conditions based on natural light is investigated. Ten different iterations are done through change of transparency in the membrane material divided into two seasons, summer and winter. The illustration shown is taken from the complete series presented in the appendix page 266.

The physical properties used in the simulations are based on the data illustrated at the Vector Foiltec website for an accurate simulation base. Each iteration is containing data of a 3-dimensional point cloud inside the building envelope.

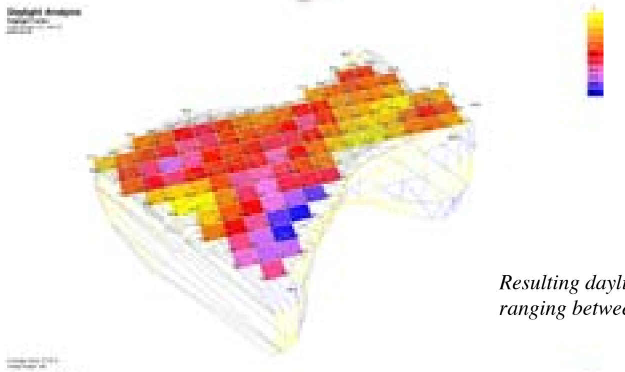
To clarify the data, three levels are chosen for illustration revealing little difference between the simulations despite of material change. This can be caused by little difference in light levels due to the dense city environment from the south, east and west, creating shaded hours on large parts of the building facade or due to a well-functioning reflective system, which equalises the intake of light via the roof throughout the year. Though the colour chart of the simulations seems identical (see appendix) reading the data reveals some differentiation in outcome of the different material choices.

Combining opaque, transparent and translucent material properties creates diverse internal daylight effects on the southern side. Most important is though to avoid a transparent surface creating glare zones within the library. As the northern, eastern and western sides are relatively little affected by direct sunlight during opening hours, a combination of transparent and translucent materiality would be adequate.

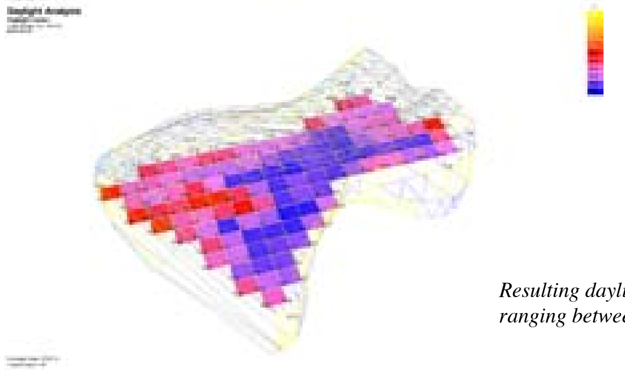
Light levels and the distribution of light through the western atrium is very good, while the eastern atrium seems to be too narrow. This can be improved by either directing more light through the envelope via an alteration of the parameters in the local system03 or as a result of widening the atrium space.

Ill. 108

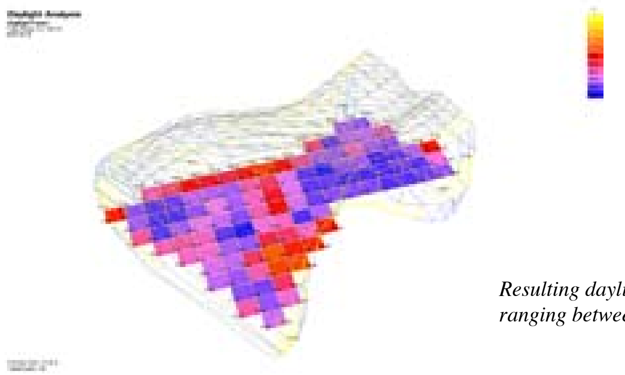
Model expression with diverse panel transparencies.



Resulting daylight factors level 5 ranging between 20-30 %



Resulting daylight factors level 3 ranging between 5-20 %



Resulting daylight factors level 1 ranging between 2-15 %

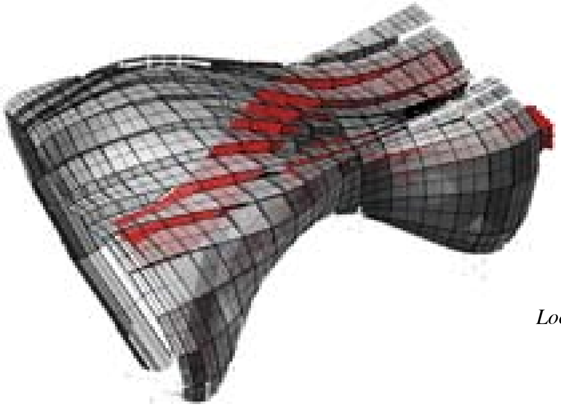
Internal thermal mass

The solar strategy presented in the operations chapter is implemented into the pre-solution local system03, through exposing thermal mass in winter periods, controlled by the parametric input.

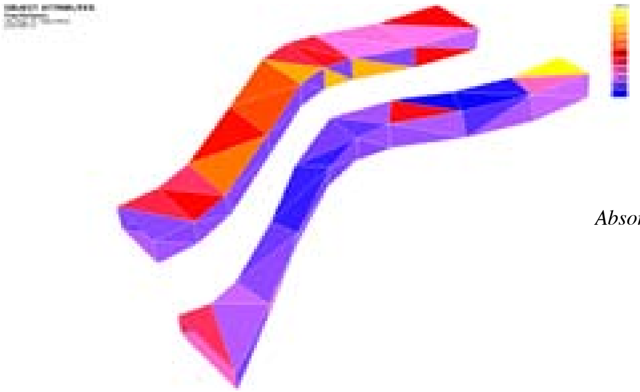
The illustrations show the two strings located underneath the envelope of the building in red colour and two simulation illustrations showing cumulative radiation onto thermal mass in winter periods and cumulative radiation in summer periods. Cumulative radiation is describing the amount of energy stored as radiation in the exposed material, which can either be transformed to electricity via photovoltaic cells or used as thermal mass.

The informed pre-solution based on heuristics show a clear use in conceptual form finding processes towards optimisation through a first generation of simulation iterations. To further improve the performance of the differentiated environmental input in relation to season an alteration of the parametric set-up is done within the following design iterations.

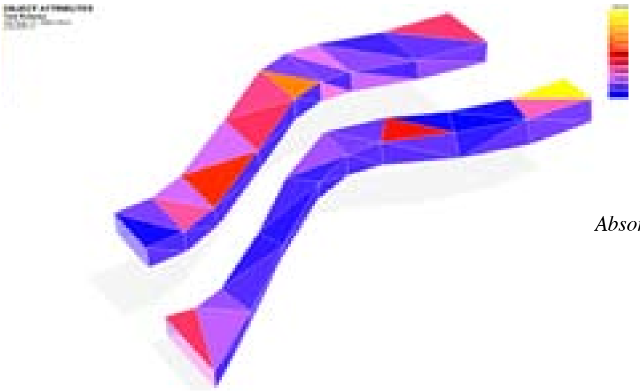
Ill. 109



Location of thermal mass



Absorbed energy in winter



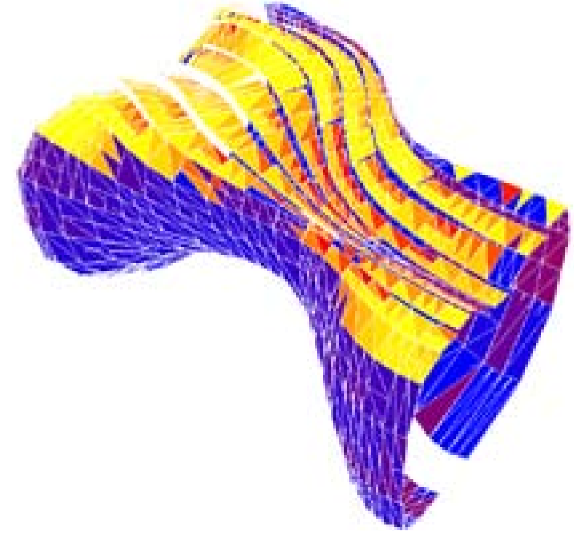
Absorbed energy in summer

External surface radiation

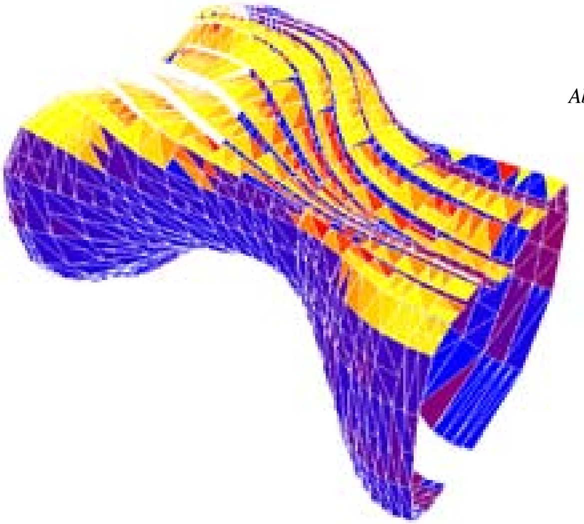
Investigating cumulative radiation on external materials can identify a series of potentials and problems. The analysis shows properties of the surface area with potentials for location of photovoltaic thin films, location of absorbing materials and reflectors.

The ill. show two simulations in the summer period and in the winter period, in which a similar radiation occur in cumulation, but large difference in values. Each panel has a minimum of 1 data set, which can be analysed and informed into the parametric model for optimisation. The aim is thereby to register possible energy gains through solar exposure on the outer surface of the building. Throughout the year are high exposure levels registered on the roof, low level on the vertical south side, while the remaining surface areas have little exposure. The cumulative radiation analysis confirms thereby also the data from the daylight analysis, which revealed little difference in light levels despite different transparencies.

A strategy of orientating the exposed surfaces to either reflect or absorb radiation would equally inform the parametric model towards improved daylight and possible energy production from radiation.



Absorbed energy in summer Ill. 110



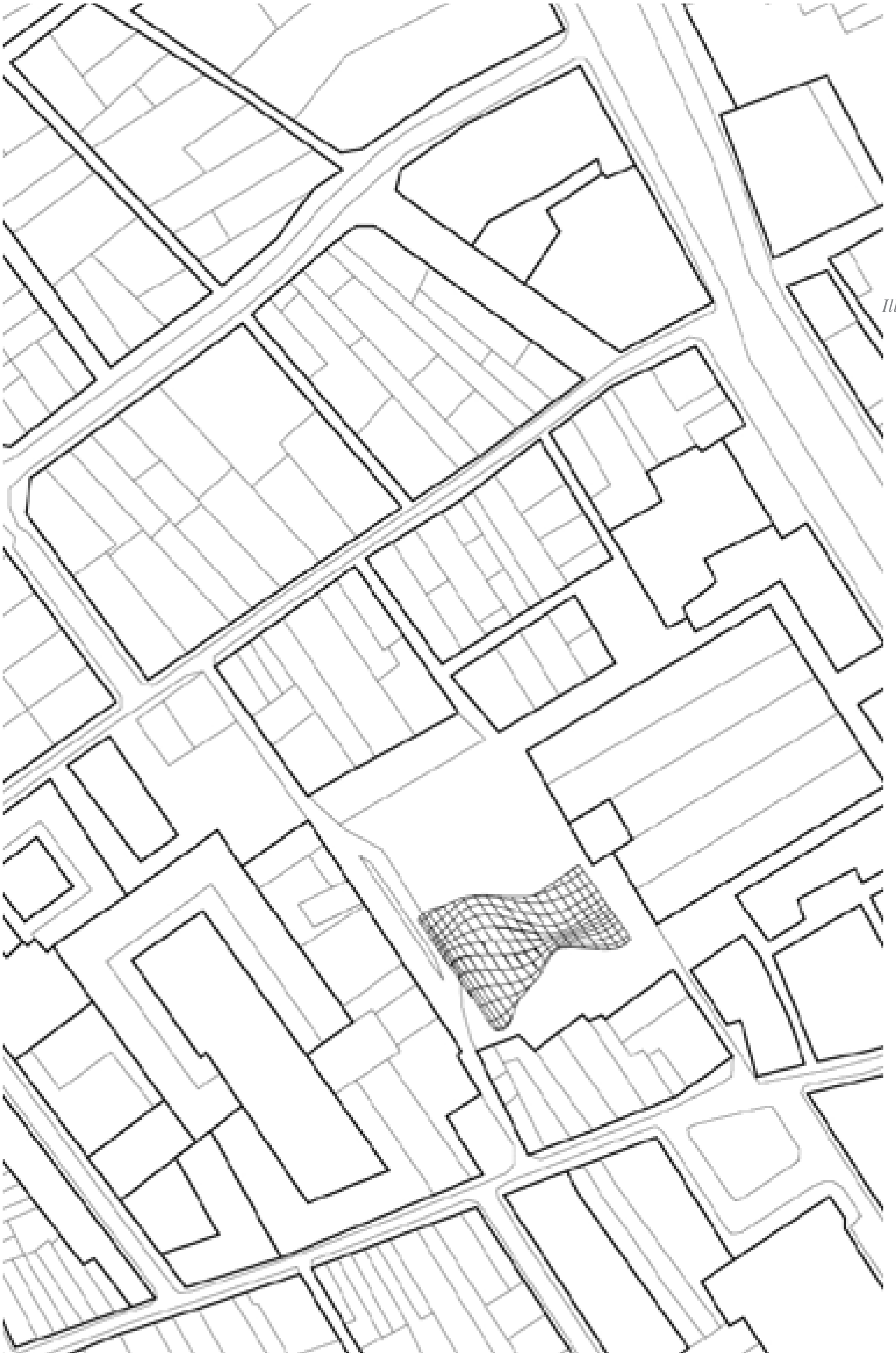
Absorbed energy in winter

Conclusion Design I

First design proposal is an enlarged variation of the final model of the topology study, giving space to the internal programme thus stretching further into the square with an asymmetrical body smallest towards Mercat Boqueria. Three points of access are possible to the space created between the library and existing buildings, creating different enclosures of the space according to position within the space. Diverse public zones are framed by movement along the continued narrow street alleys, Pl. Gardunya or the smaller garden.

The building continues neighbouring lines from the market, accelerates and dissolves them as a catalyst, broken open in both ends by the cut from the city flow. The library is an enclosed institution but seen exposed by the direct contact to the external flux and environment, following and contradicting the urban movement in ground level and from the roof tops.

To elaborate the building characteristics, a series of global design modulations are created in Design II, taking advantage of the parametric system in free performative form finding.



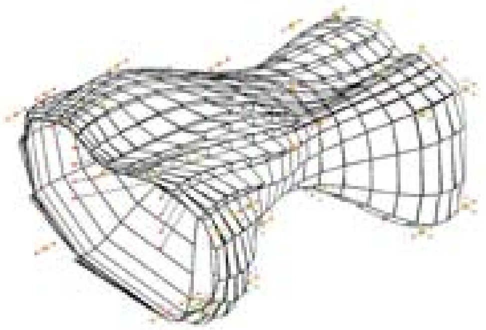
Ill. 111

DESIGN II

Progressing the building layout using the associative design set-up and alteration of parametric variables gives freedom for global modulation taking effect within internal and external spaces. Plan boundaries controlling a height to depth ratio as previously described are incorporated, following the form change enforced by the designer. With a change in building depth, the atria spaces will consequently enlarge or shrink whilst the envelope will grow stronger with larger distance between the south façade and the north façade to obtain the enlarged span. A relation between structural strength and plan depth can then be related to porosity of the building. As the structure enlarges its distance between the inner and outer plane, the cross plane will open as an iris, allowing more light to penetrate the building skin, as a relation to plan depth.

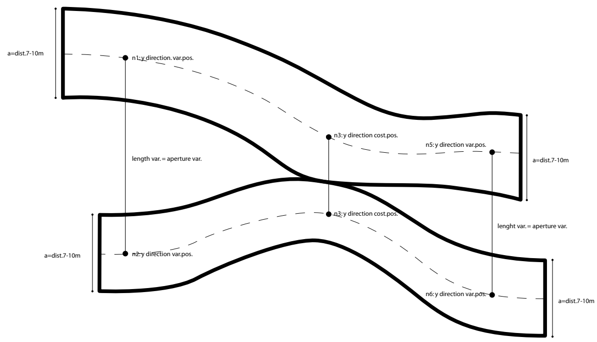
A series of design proposals are consequently created, with emphasis being put on spatial environments in plan, atria and surrounding spaces. The associative/parametric construct allows thus for design freedom due to the informed system, re-optimising its configuration for every design proposal.

Global 1
Generative Components model

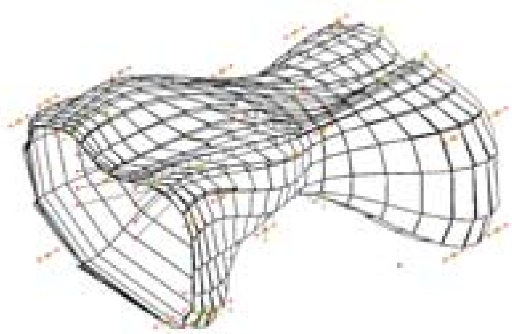


Plan transformation

Ill. 112

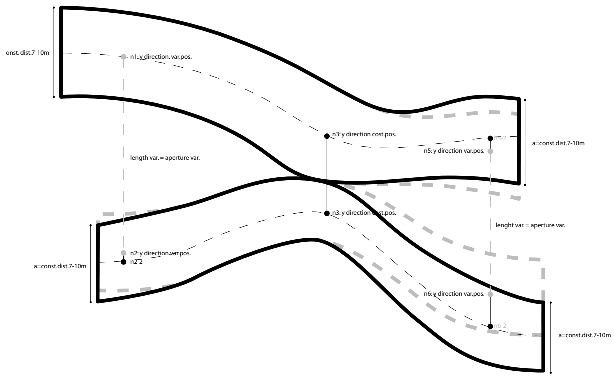


Global 2
Generative Components model

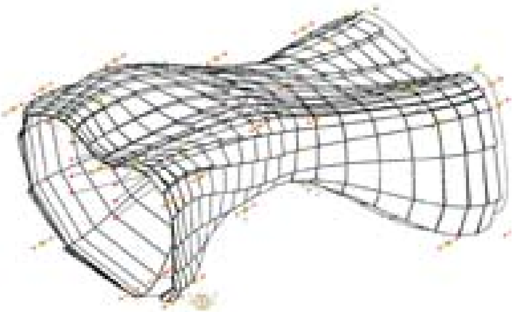


Plan transformation

Ill. 113

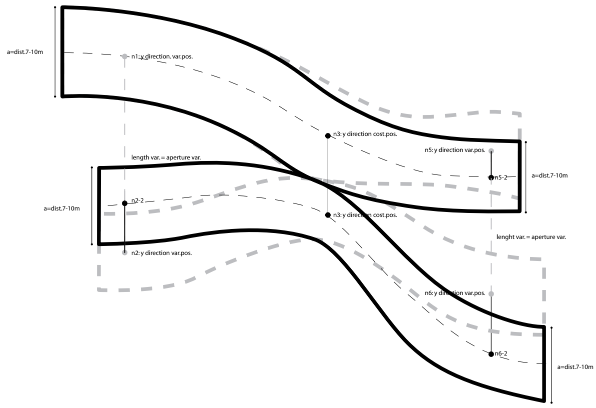


Global 3
Generative Components model



Plan transformation

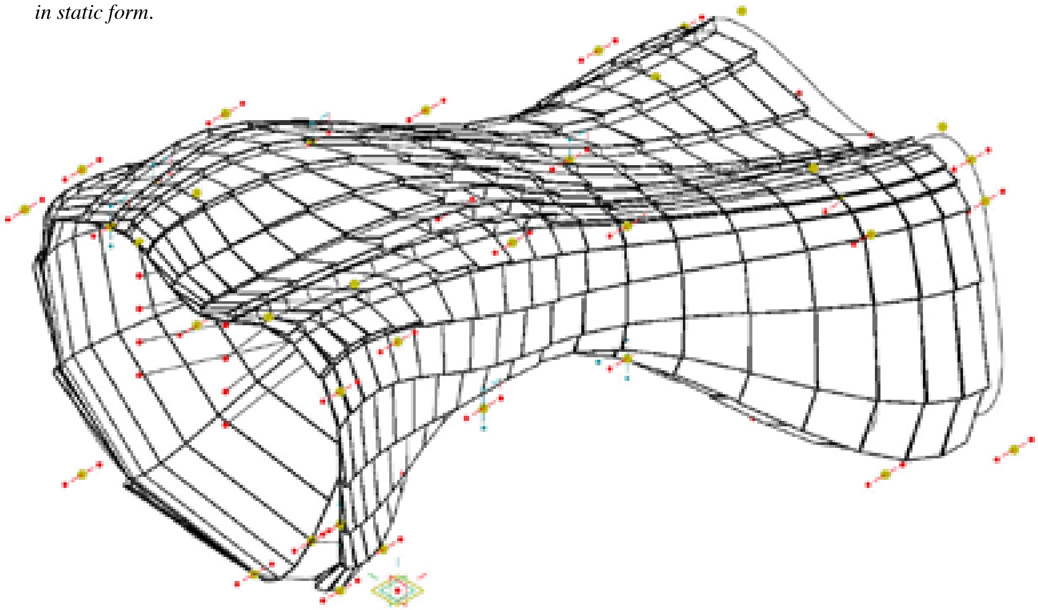
Ill. 114



Ill. 115

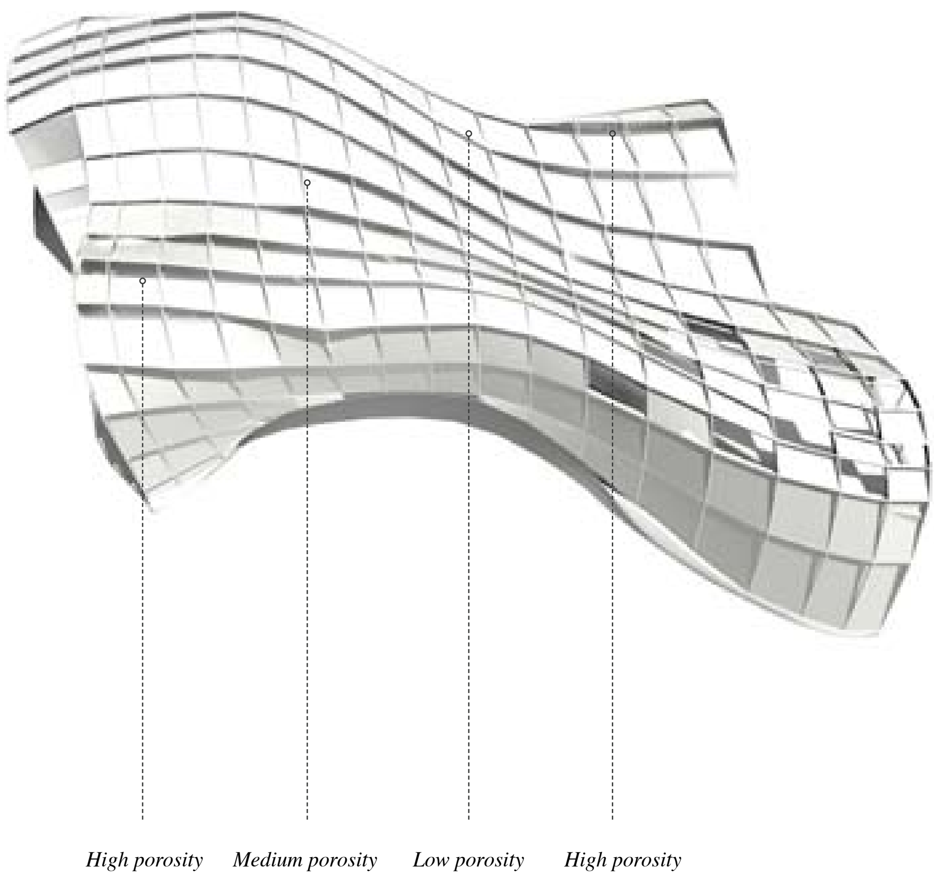
Global 3
Generative Components model

The nodes of the model with imbedded data modulates the internal and external spaces, while altering its porosity to perform dynamic behaviour in static form.



Generated porosity and structural strength is the result of the relational construct described above with the illustrated selection of the form finding series. Different zones receive, reflect and absorb daylight according to spatial requirements. Gradient porosities are thus detected throughout the library zones, responding to both theoretical concepts presented earlier through natural systems and to direct implication of daylight factors registered in simulations and daylight effects of light and shade.

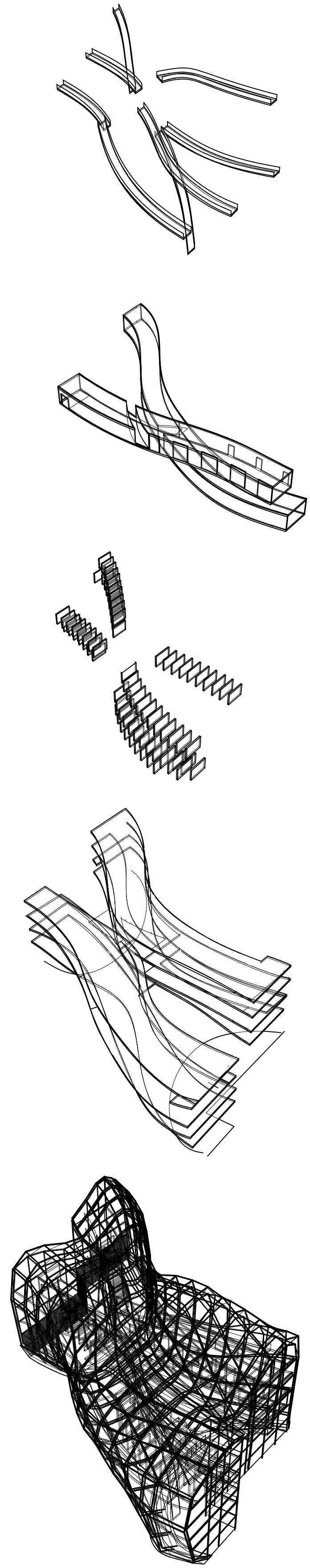
Ill. 117
Differentiated porosity



Design II internal

Linking the internal organisation to the global form, modulating the organisation according to external and internal spaces simultaneously creates a design environment responding to spatial, sustainable and structural aspects by every movement. Internal constituents are thus unchanged from the previous design, but reorganised. This has implications to the eastern atria by becoming larger as respond to the daylight simulations from Design I by distancing and dislocating the two plan strings. Movement of the internal spaces are similarly changed as they now follow a curving rhythm in crossing the building from east to west, which then also alters the external garden space, following the neighbouring building closer to create a more intimate ambience.

Movement paths are shortened and distributed with a minimum of four exit/entrance points excluding the elevator giving a free flow in axial path lines. Lowering the internal volume to be heated during winter periods, connecting downward to the lower lying buildings and diverse reflecting surfaces force the roof over the atria inward. This creates a more dramatic meeting between the building elements from all positions within the library.



Visitor movement

Studios

Ill. 118

Bookshelves

Open reading, study, meeting

Structure and membrane added

Daylight study/design II

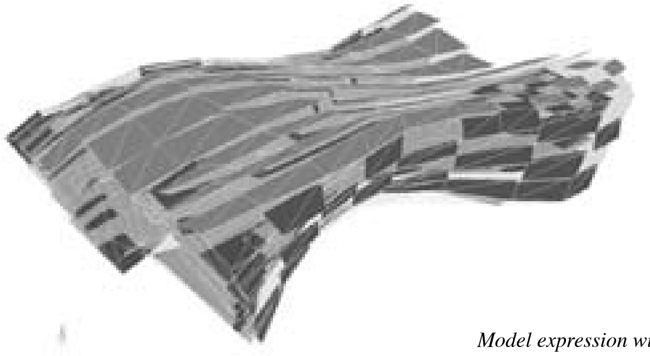
As a respond to prior daylight simulations, the aperture of the local system is altered as well as series of global formations, changing conditions upon how light falls into the building. This has enlarged the atrium space to the east, kept a height to depth ratio of app. 1:2 with improved factors as a result.

Three simulations with diverse panel organisation are done (one is illustrated here, with the remaining two in the appendix) to recognise light levels and light effects. 01) symmetrical pattern in chess board organisation 02) with slightly more opaque than transparent panels and 03) with irregular pattern organisation, but in relation to internal programme. All three simulations reveal daylight factors from 2% in the darkest areas to 60% near the envelope.

The organisation of panels is to be considered with thoughts to light levels, the space it frames and the architectonical expression. All charts reveal high light levels, as also recognized in the previous daylight simulation, but also with glare in the zones where panels have been removed.

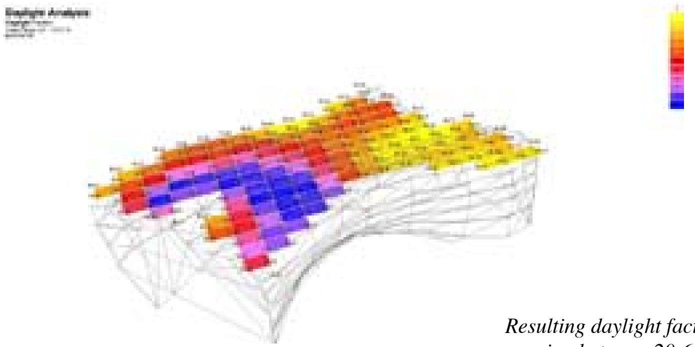
As a consequence of the good light levels performed by the system organisation to allow light to penetrate the building, a composition with full panels applied is chosen to create a stronger structural frame, clarify the architectonic global building body and to clearly create a framed and open library building at once.

To verify the light levels with a complete paneling system a third simulation series is done in Design III.

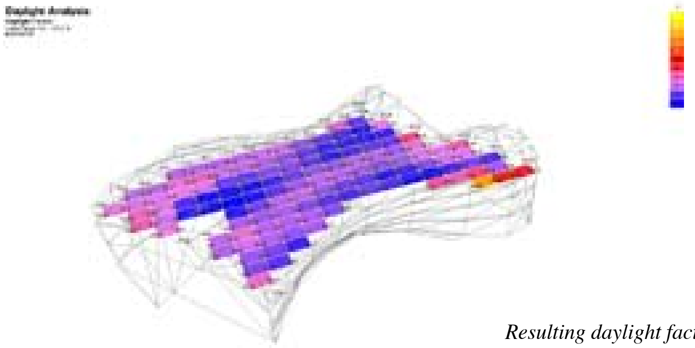


Ill. 119

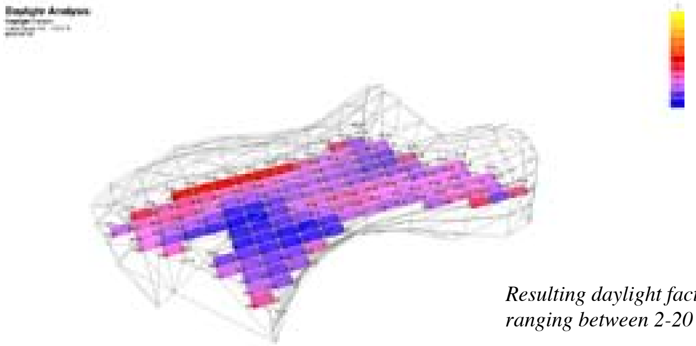
Model expression with diverse panel transparencies.



Resulting daylight factors level 5 ranging between 20-60 %



Resulting daylight factors level 3 ranging between 10-20 %



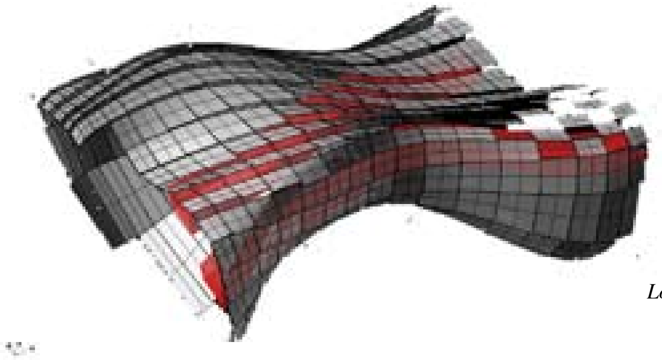
Resulting daylight factors level 3 ranging between 2-20 %

Cumulative radiation/internal

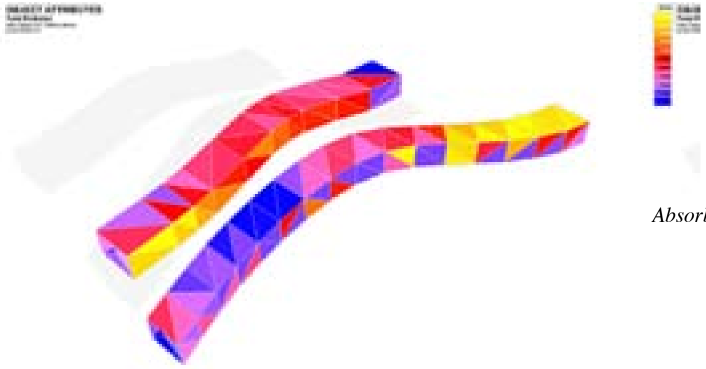
Alteration of the parametric input controlling aperture throughout the envelope has created improved internal absorption of energy. This is done in relation with changes in the internal organisation. The pure yellow indication on the right illustration (summer period) is misinformation to the reader as the open air cafe is located here, exposing the thermal mass to the outside, with little effect to internal temperature changes.

A detailing of colour implementation and material application will follow the information derived from the simulation/analysis. Black is thus located to improve the absorption of solar energy further.

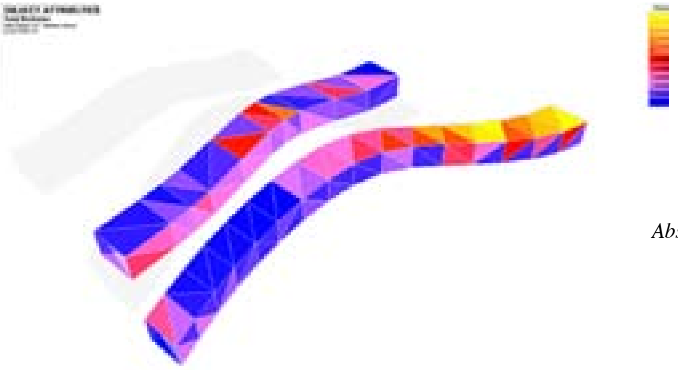
Ill. 120



Location of thermal mass



Absorbed energy in winter



Absorbed energy in summer

Design II conslusion

The dislocations of the strings are clearly visible in its context, emphasizing the dynamic and differentiated body, maintaining open, broken connection to the city. From positions within the library at the end of each string are viewing posts located with direct visual communication to the market, the eastern side of the square and along the western street to the south with public terrace.

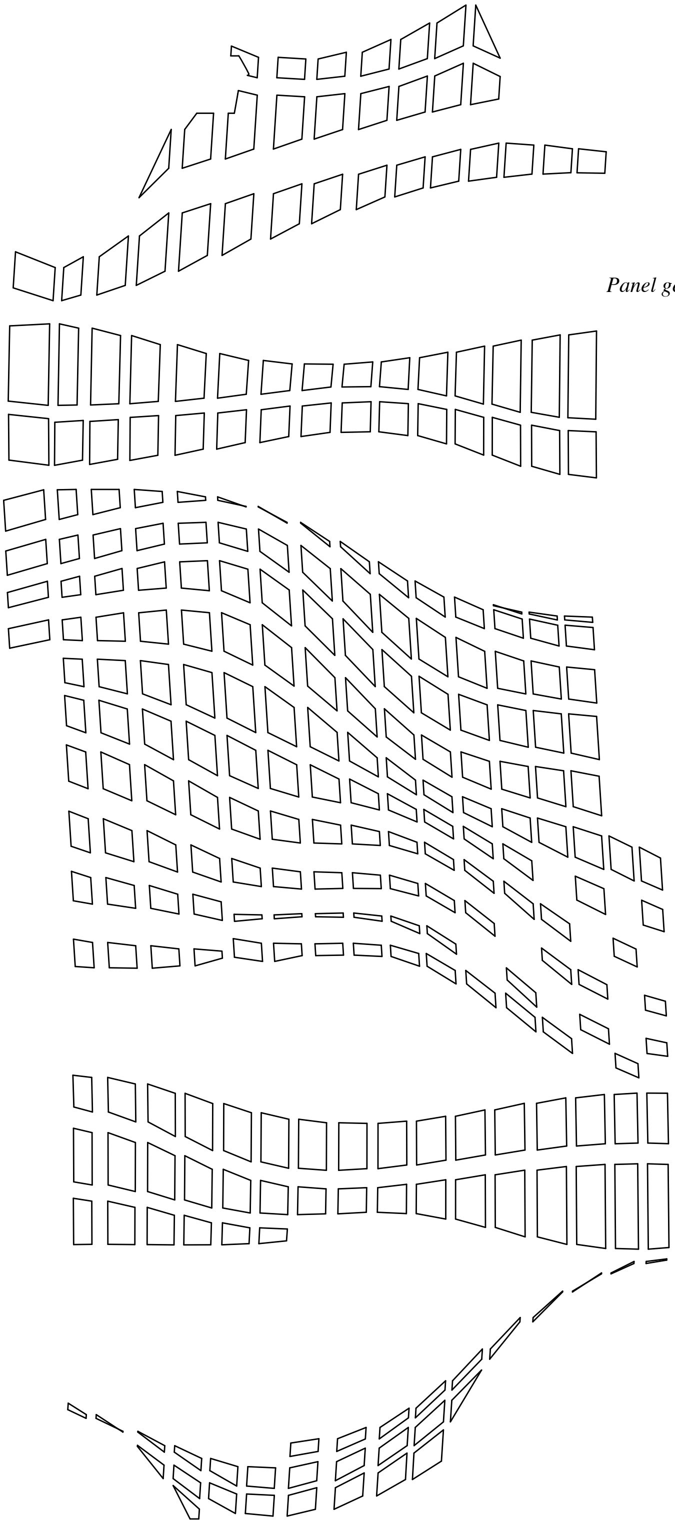
The movement of the building ensures a larger square space for public activities during the course of year and creates a clearer image of the market building. Flow lines prior described are maintained while at the same time being relocated into a more balanced building with improved internal and external spaces.

Ill. 122

DESIGN III

The chosen model designed/generated from the previous iteration series is further developed with the intention of detailing daylight conditions and energy absorbing conditions through colour differentiation. Properties of white and black orientate the panelling design to its optimum use, reflecting light into the library and generating energy through location of solar thin films in most exposed areas of the surface.

In addition to the detailing of the panelling of the north-south axis surface, are east and west facades treated with a filtering layer, creating a more varying façade without blurring the design intention of the open framed library space. Louvres are used for filtering, located as respond to expressions of internal spatial enclosure and a cumulative radiation analysis orientating zones with higher solar exposure.



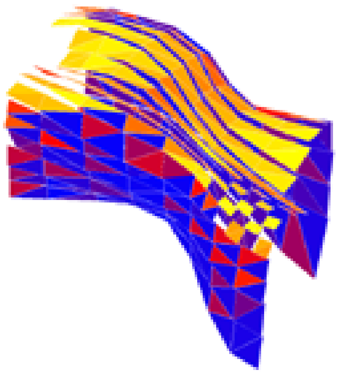
Panel geometries nested in plan

Ill. 123

Daylight study/design III

A simulation series is done with focus on colour differentiation and the respective effect. The building is simulated with full panels, to keep maximum structural strength within the system. Two iterations are done with white roof and black roof (good reflector or good absorber – see appendix), to detect the differences in light levels. The white roof performs naturally better, but absorbs equally worse in collecting energy from the sun. A new simulation of cumulative radiation is done to determine precisely where energy can be collected most efficiently.

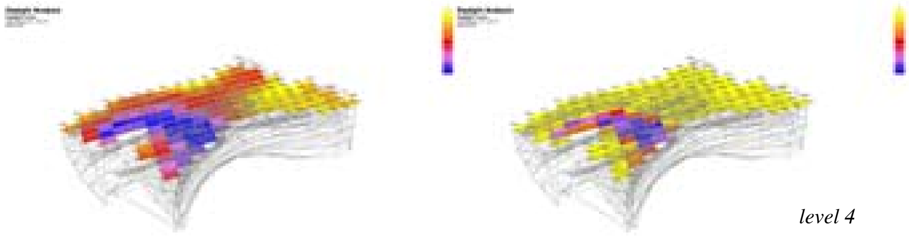
The two rows of ill. to the right show the optimum combination of black (absorbing) grey (absorbing and reflecting) and white (reflecting) panels in order to keep high interior daylight factors and actively take use of the solar energy through solar thin films placement. The simulation furthermore shows daylight factors ranging between 3 and 70 from the darkest places to the location near the envelope, but with a large majority of the spaces being lit with 5-10%.



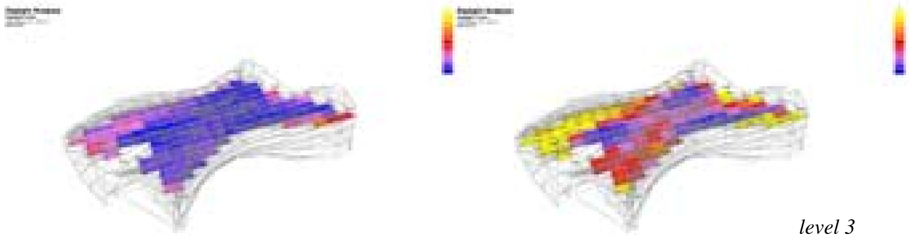
Ill. 121 *The cumulative radiation simulation of the surface identifies areas, which have better conditions for absorbing energy, which will be further emphasised by colouration.*

Interpolation range 0-100% *Interpolation range 0-20%*

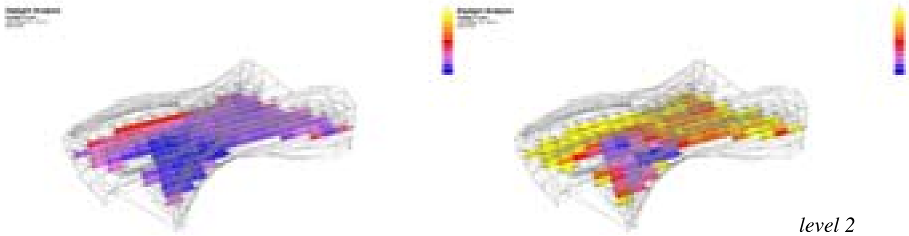
panelling expression Ill. 124



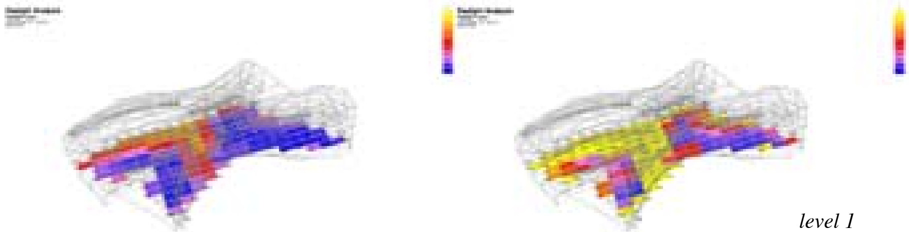
level 4



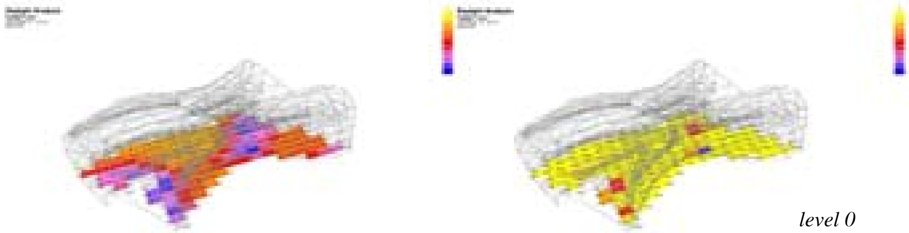
level 3



level 2



level 1

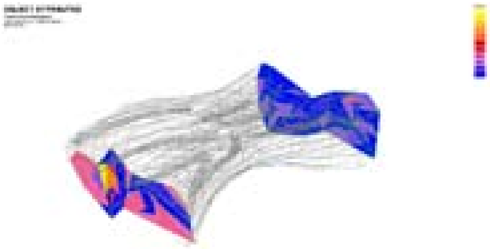


level 0

Daylight study/design III

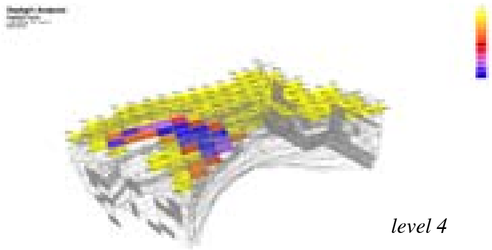
A final simulation series is done to incorporate daylight filtering of the east and west facades, to differentiate the large simple facade and create a scale relation to the surroundings and visitors. A cumulative analysis is first simulated to detect any glare zones. As these hardly are present, as prior argumented, due to orientation and surrounding buildings, placement of the filter (louvres) can be done in the few zones with slightly higher radiation and through the effect of internal enclosure. Louvres are chosen to create a layer between the internal and external zones, without removing the expression of an open continuous building.

Cumulative radiation

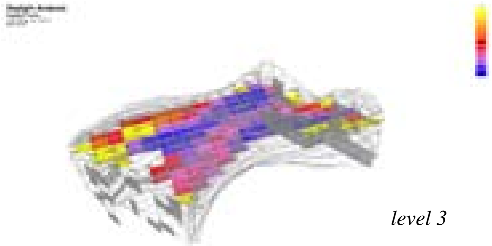


Interpolation range 0-20%

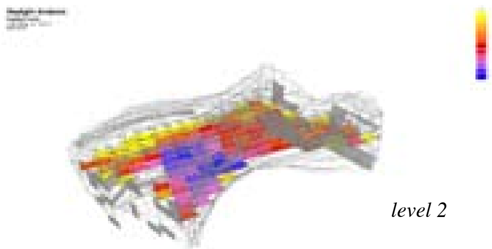
panelling expression Ill. 125



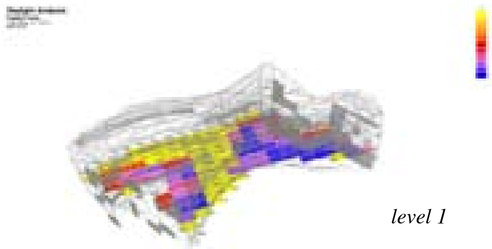
level 4



level 3



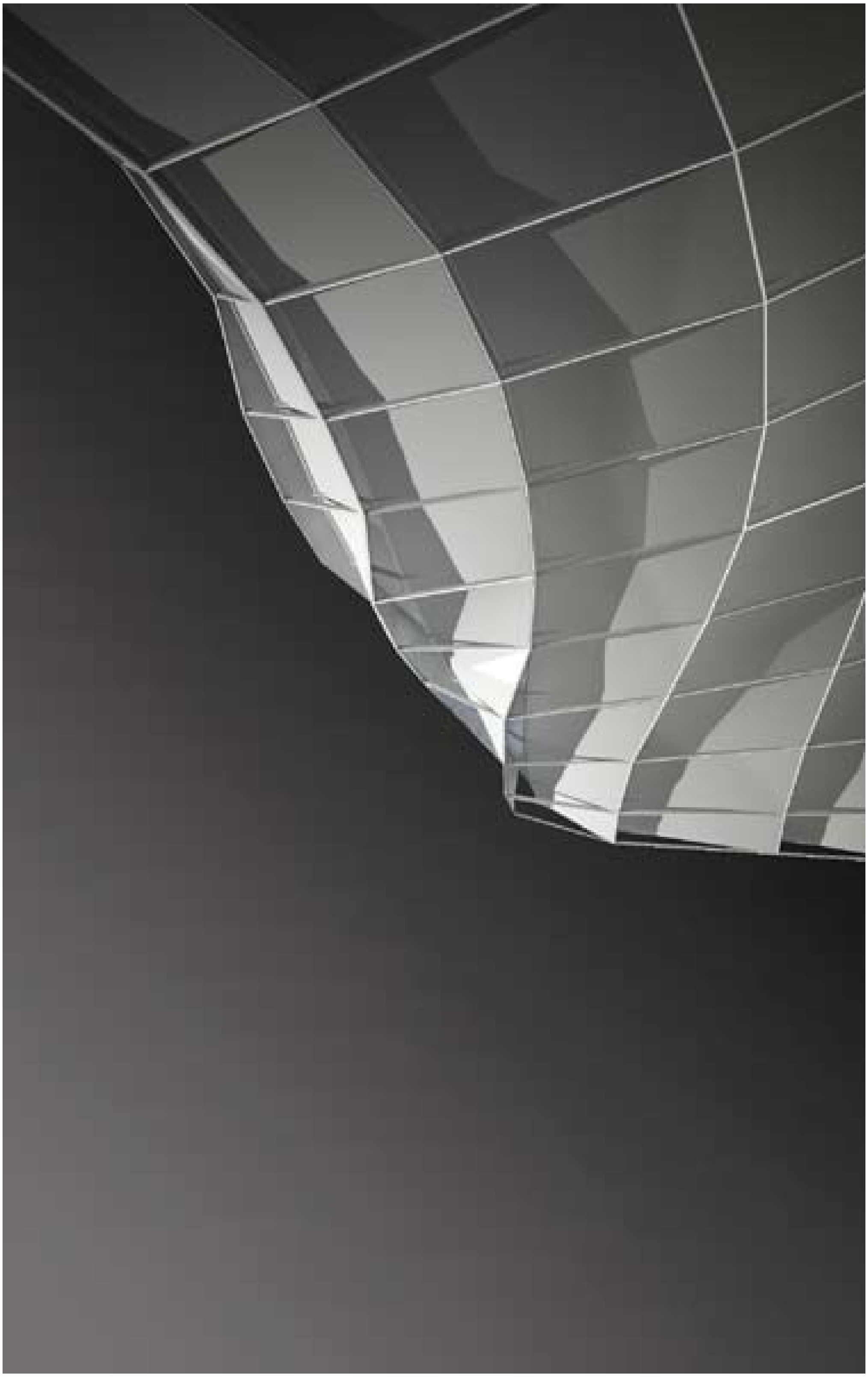
level 2



level 1

7.0 NEW RAVAL LIBRARY

Ill. 126



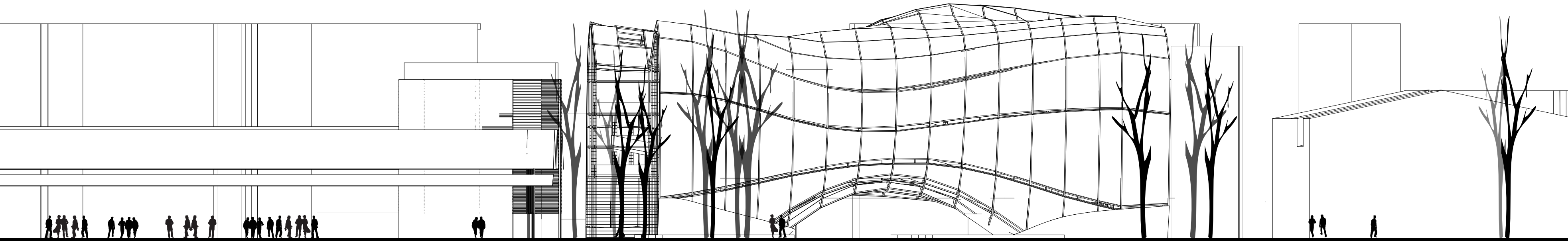
Ill. 127

A new library and public area in form of a square have been designed in order to create public encounters in diverse environments outside and within the library space in locations ranging from open to more enclosed areas. The square takes its reference to the surrounding grid, contrasting the dynamic building to emphasise diversity in the vibrant city zone of Raval.

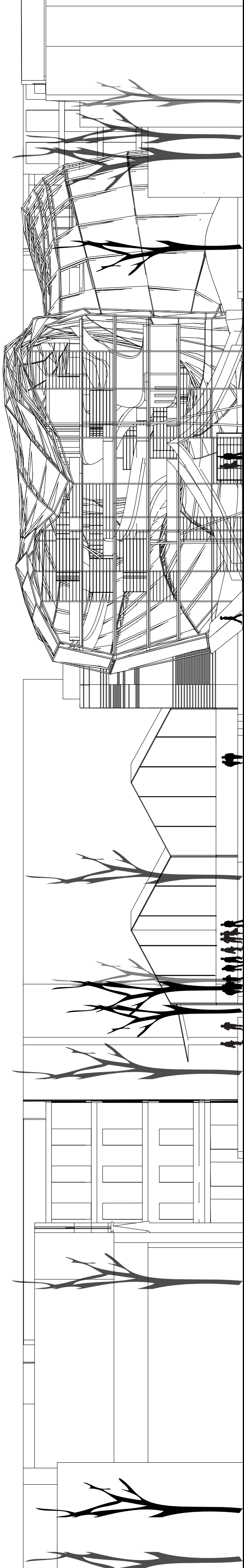
Ill. 128

South elevation
1:500

Ill. 129



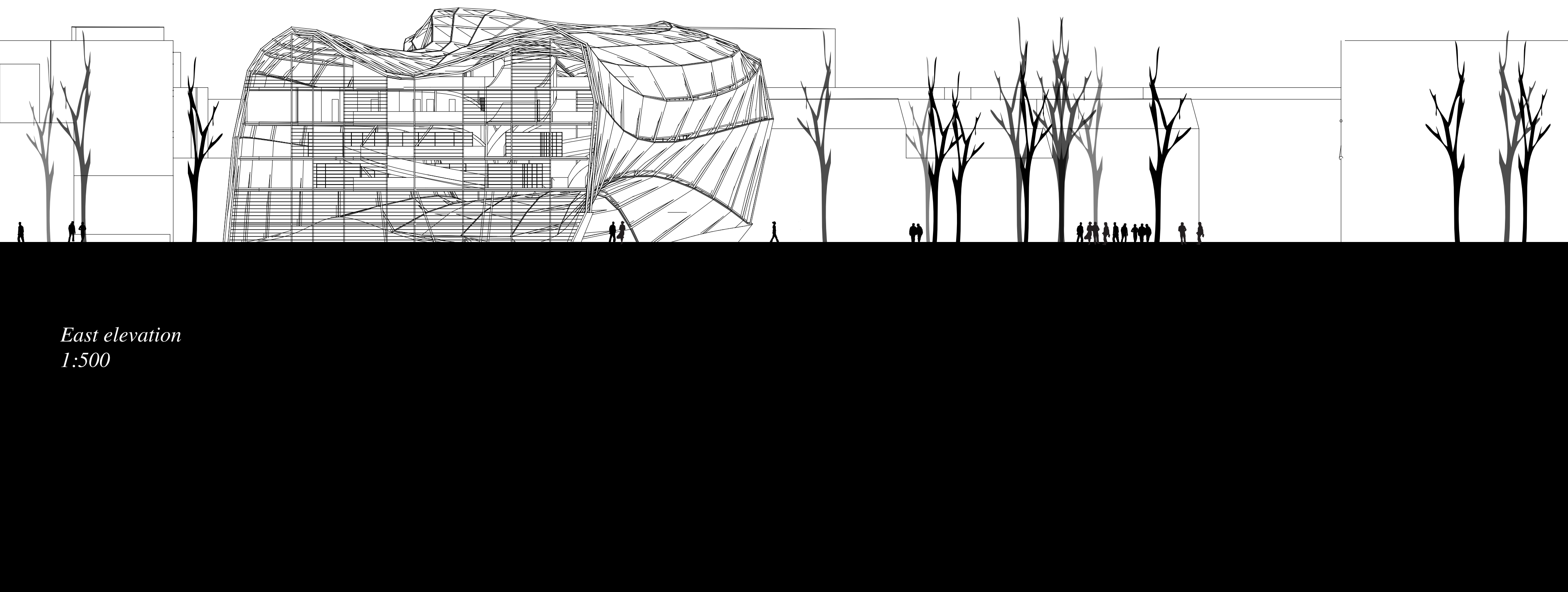
North elevation
1:500



West elevation
1:500

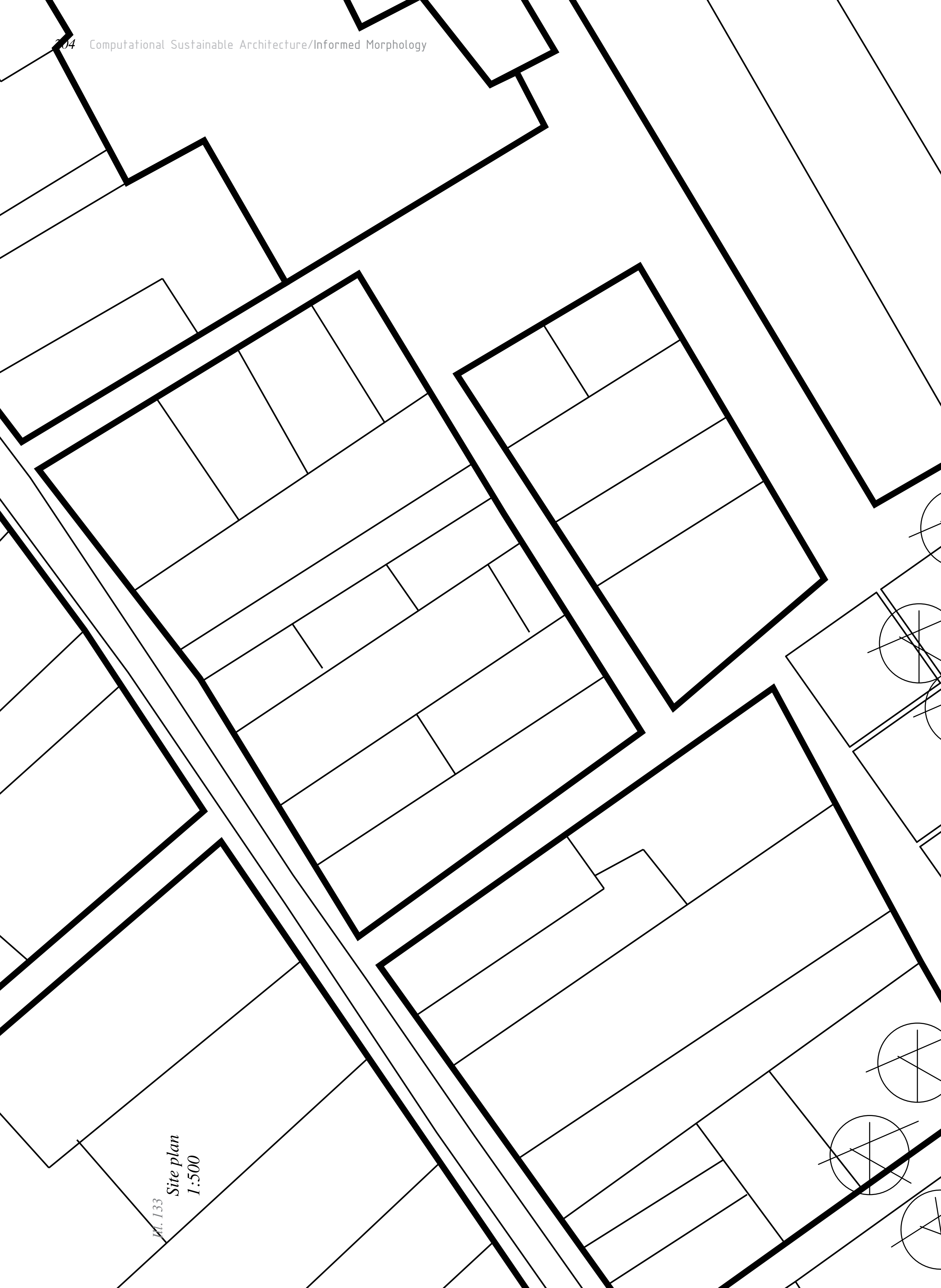
Ill. 130

Ill. 131

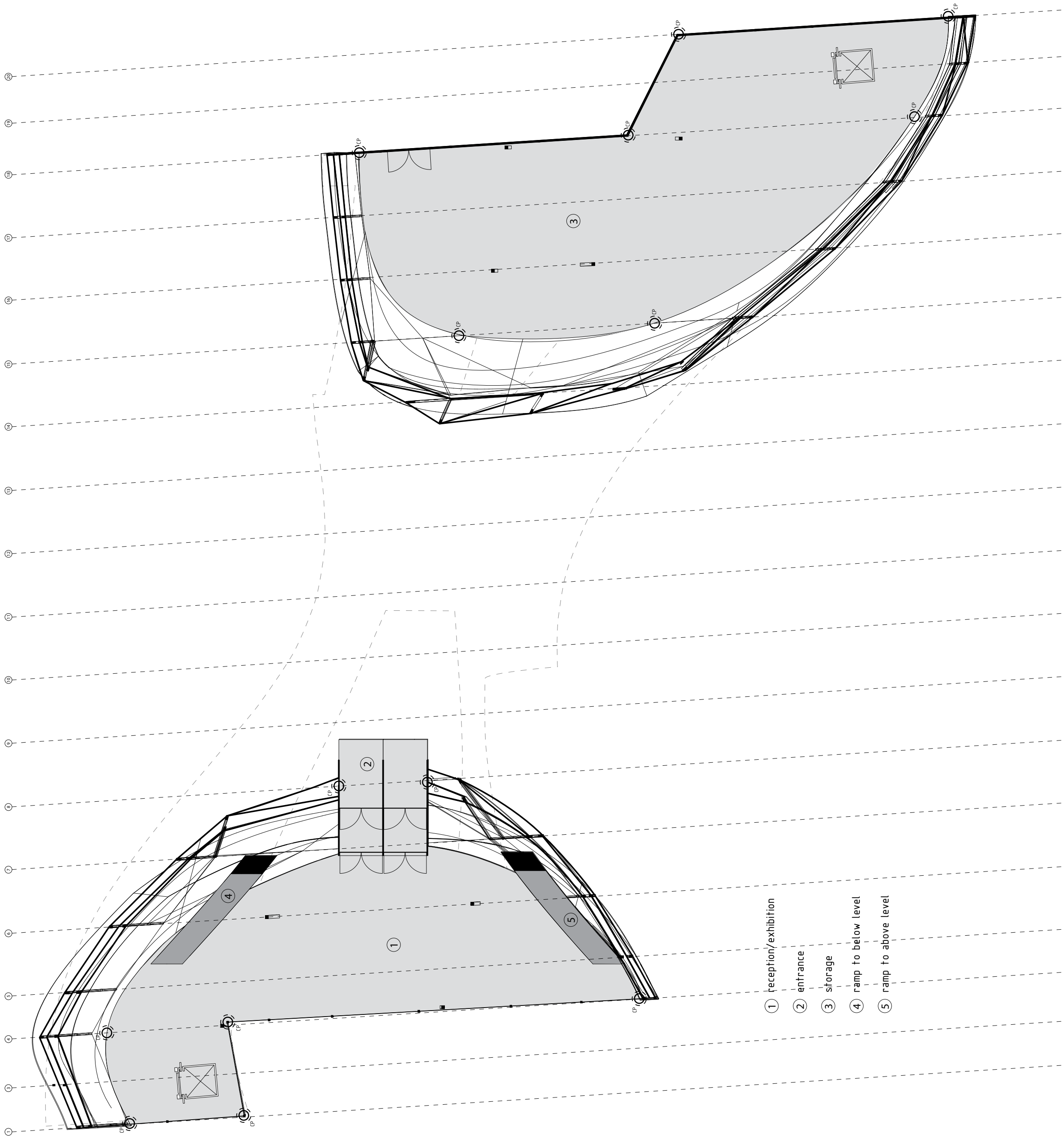


East elevation
1:500

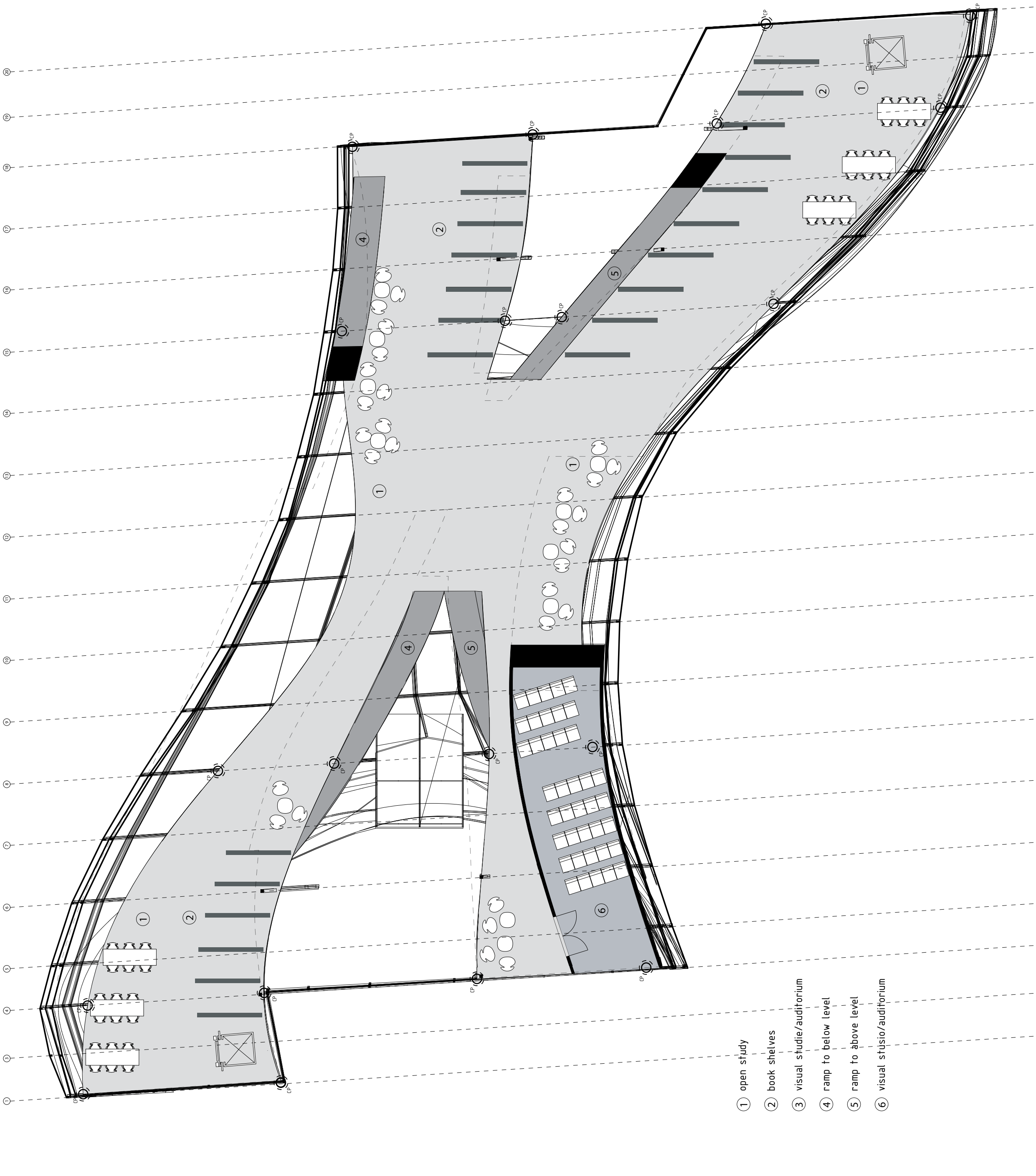
Ill. 132
Trees surround the library stretching out from the garden, positioned between the library and the adjacent building wall, to create shaded and sunny areas, while the building twists its skin to perform a similar effect within the library.


M. 133
Site plan
1:500


N



Ill. 134 **Level 0 1:300**



Ill. 135 Level 1
1:300

Ill. 136

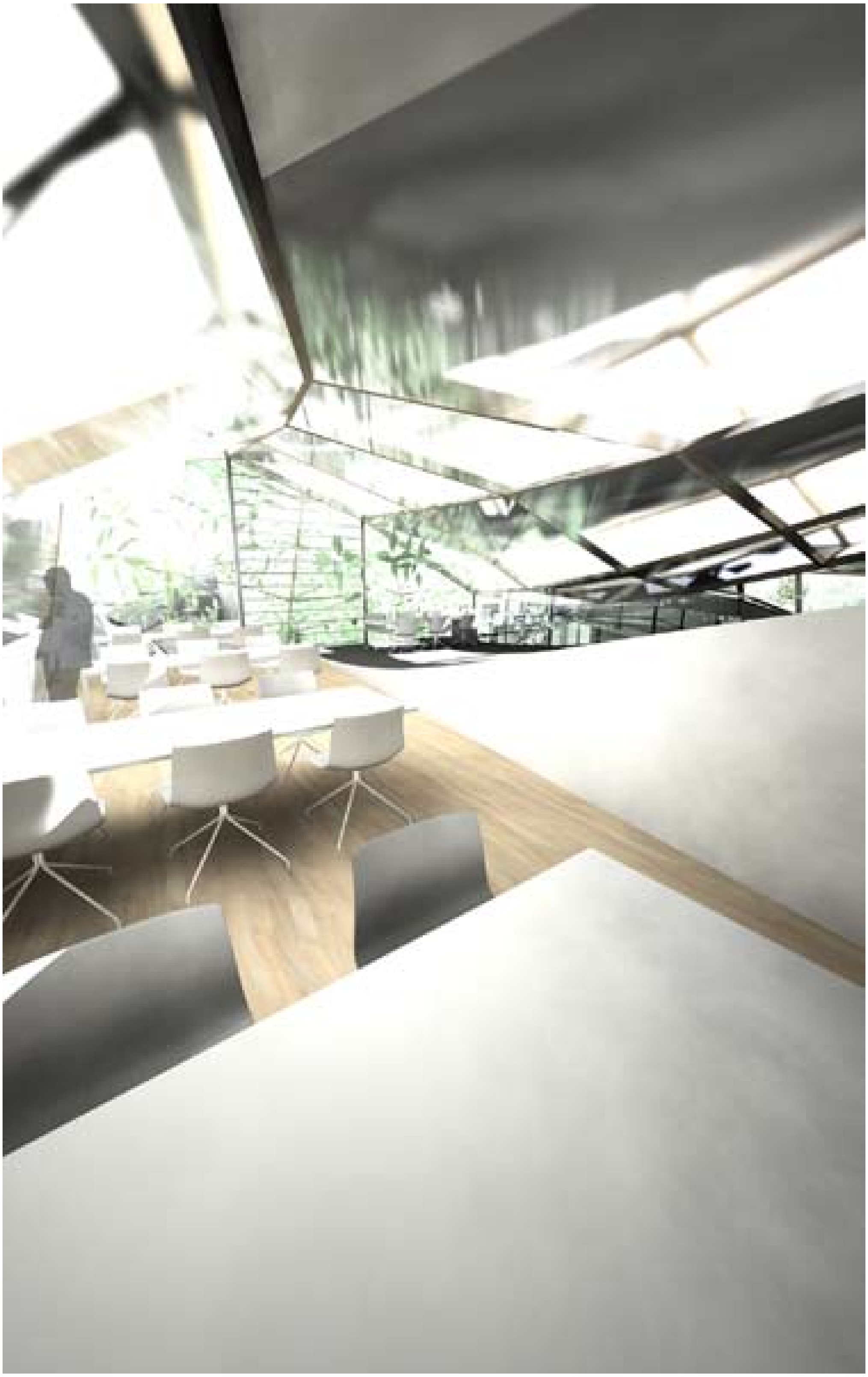
Daylight floats in from above and down via the atrium created by the chromosome layout, creating high levels of diffuse light, comfortable for prolonged, relaxed reading hours, giving a light atmosphere that is strongly contrasting to the one found in its older sibbling. Natural ventilation flows the opposite way from the sliced northern side of the building, distributed via the atria and out via the roof.

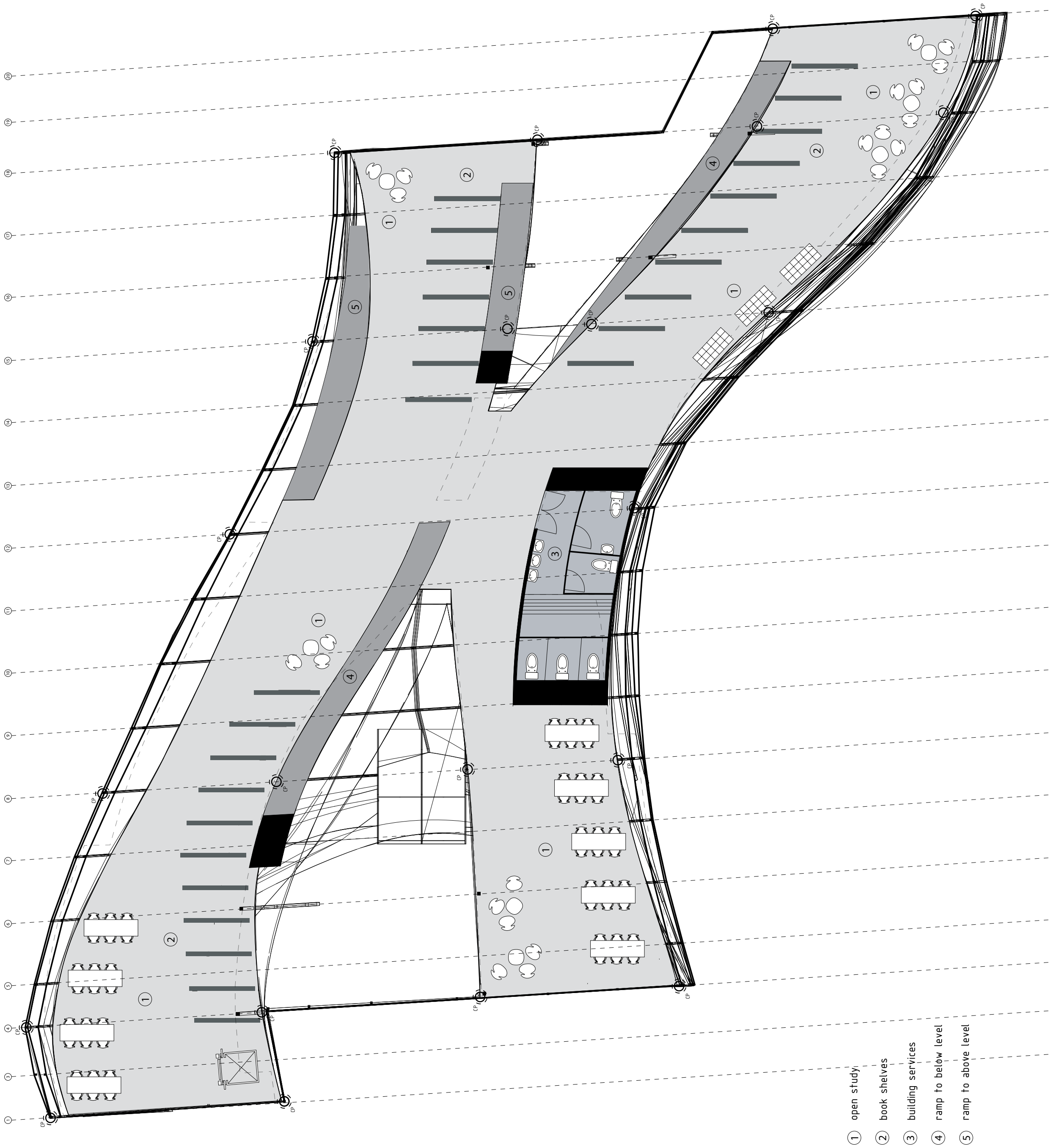
Visual communication is kept and broken through movement, as the bookshelves location and orientation opens and encloses the visual space towards the interior and the life on the square.

Ill. 137

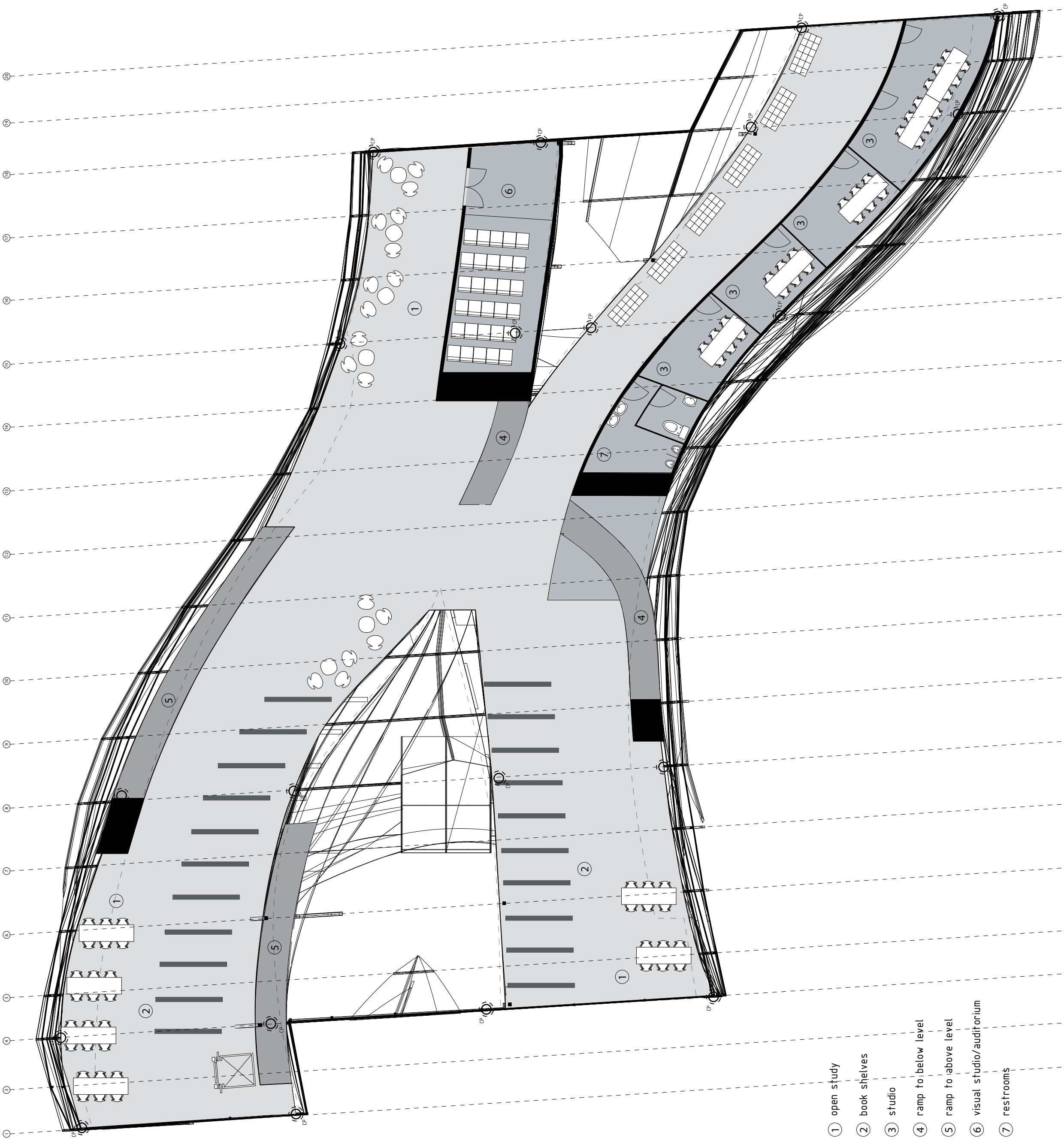
Light and space are created for concentration in study clusters with diverse enclosures and views, from the feeling of a garden space, to the urban fabric surrounding the library.

Contradicting to old dark libraries the daylight is filtered through the building directed to the zones where it is most needed in a light dynamic frame inspiring visitors to knowledge and information exploration.

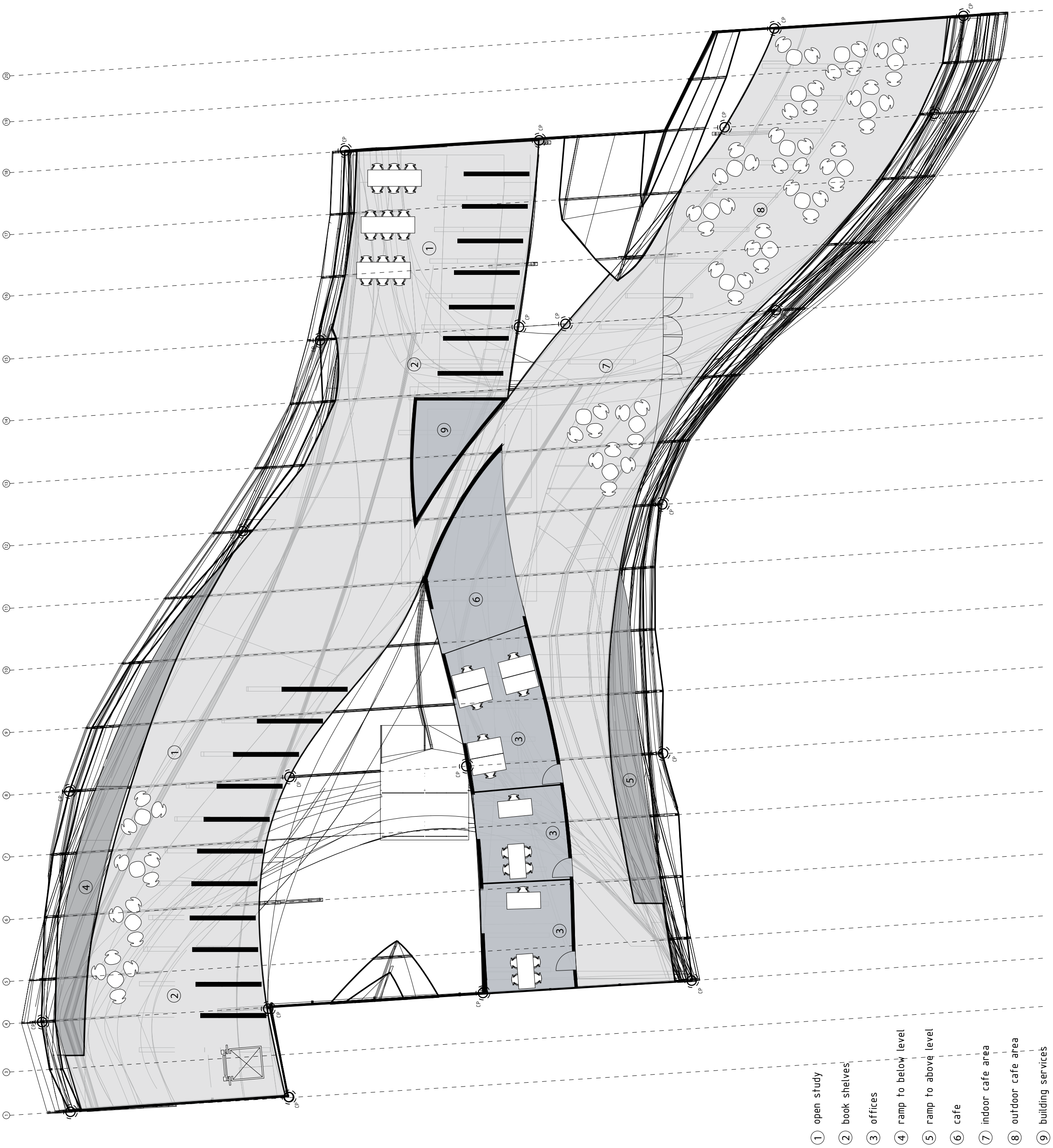




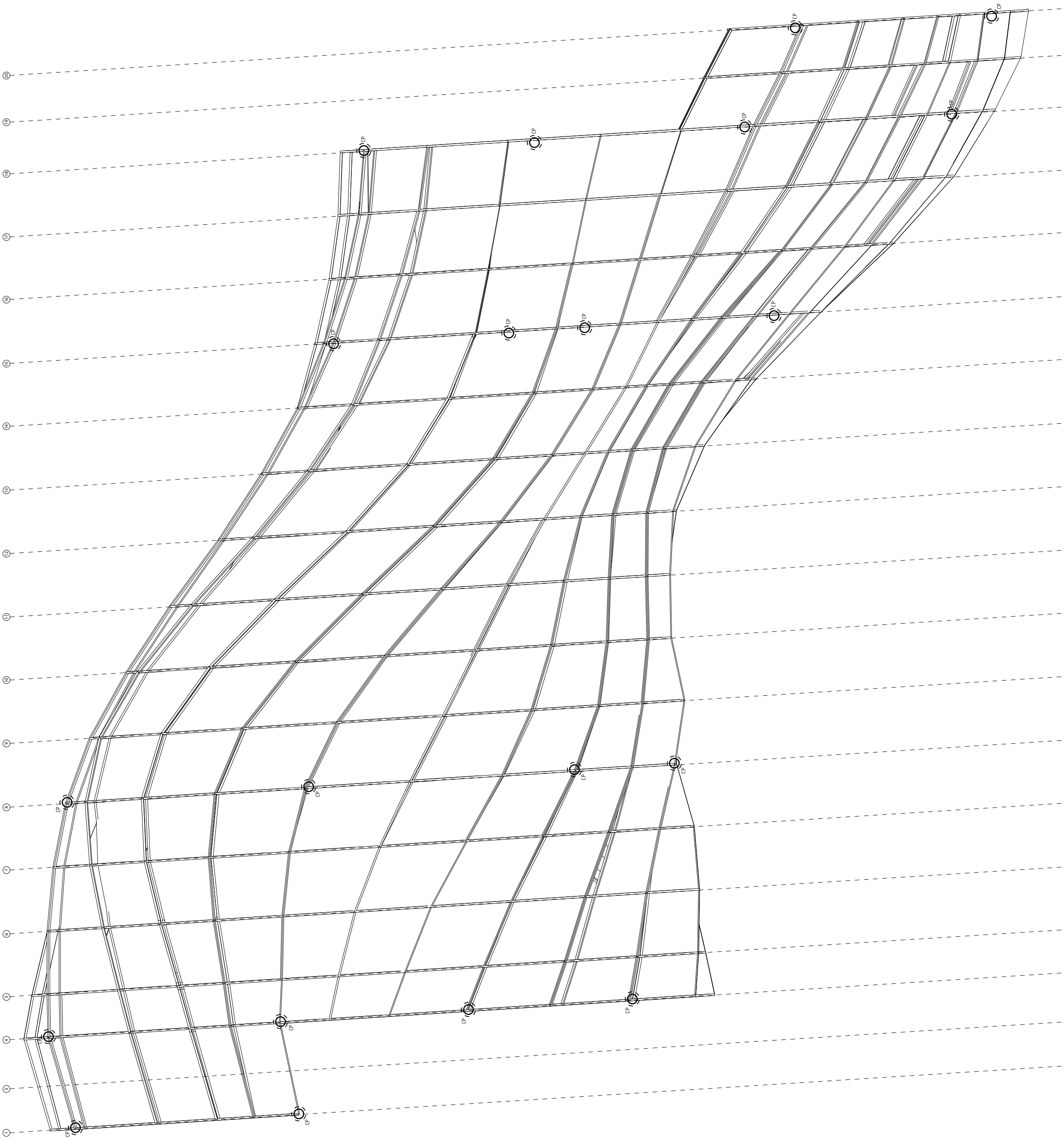
Ill. 138
Level 2
1:300



Ill. 139 Level 3
1:300



Ill. 140 Level 4 1:300

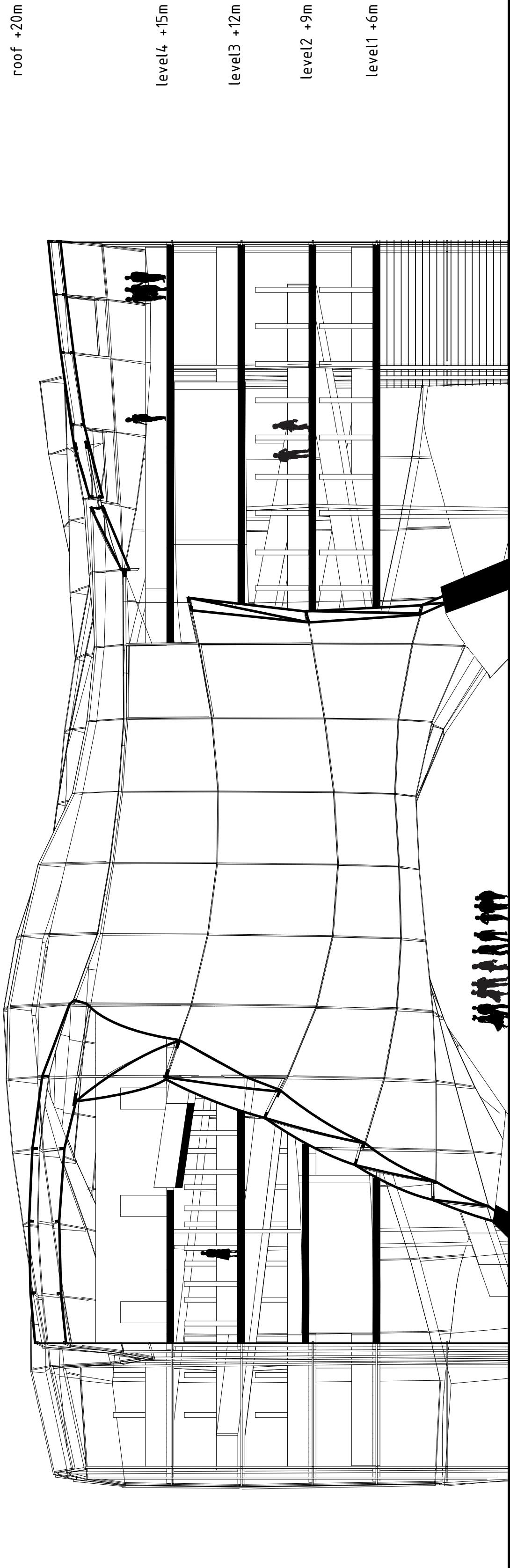


Ill. 141 *Roof*
1:300

Ill. 142

A constant enclosure and communication to the outside is created with the large openings in the building's skin and the surrounding building frame, while moving through the house between solid volumes, open spaces and rows of shelves.

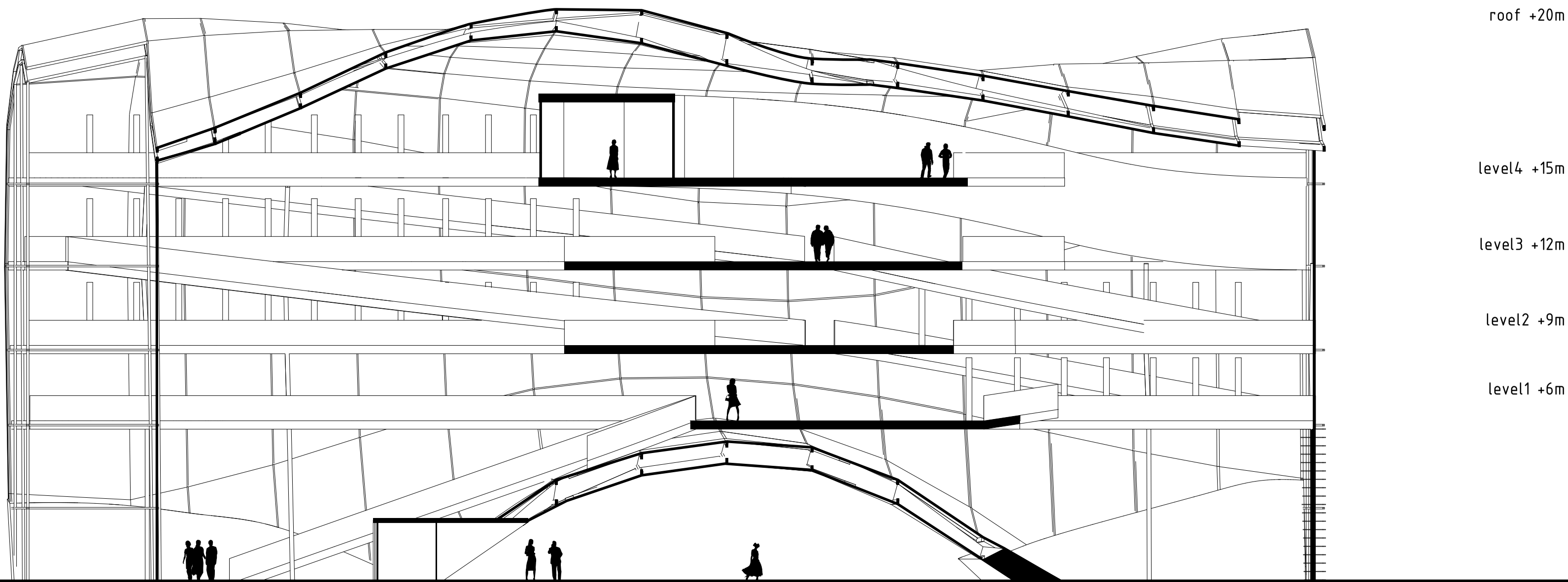
Atmosphere is made calm by the dark wooden bookshelves, referencing back in time, just below the dynamic informed morphology streaming across the library. White ceilings distribute daylight with the pale wooden floors, being in constant negotiation with the saturation balance to the dark shelves.



Section AA
1:300

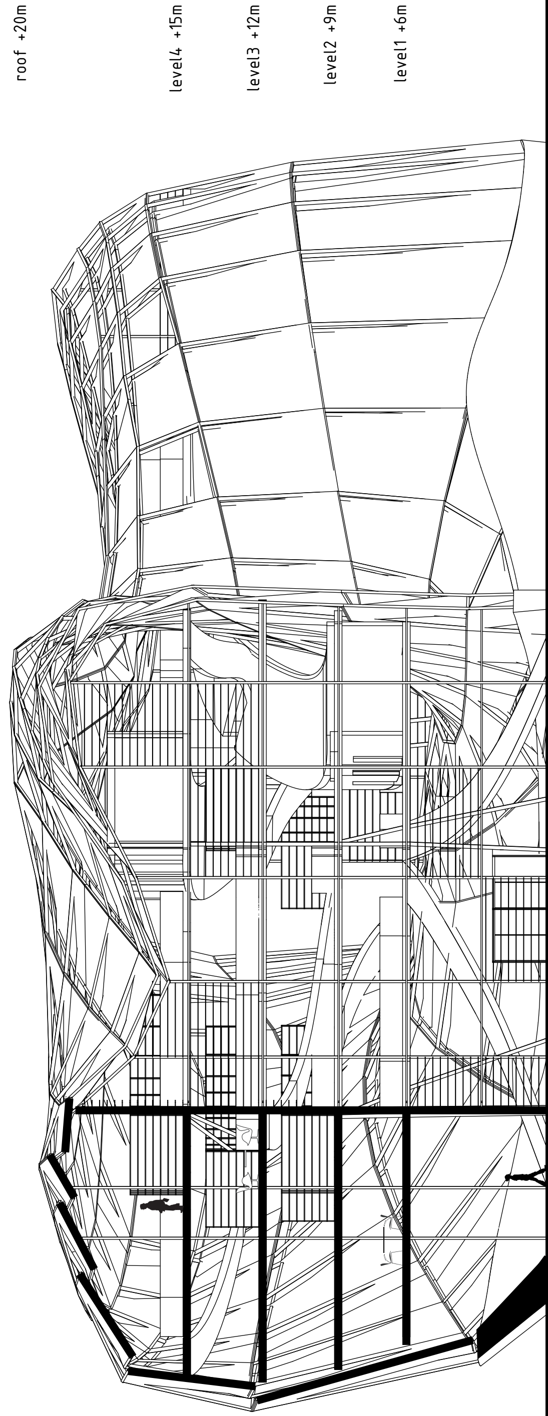
Ill. 143

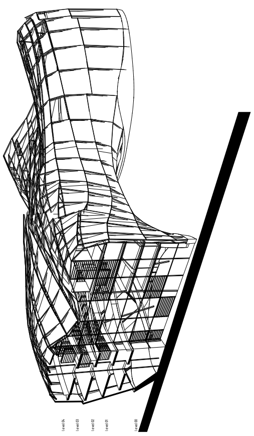
Ill. 144



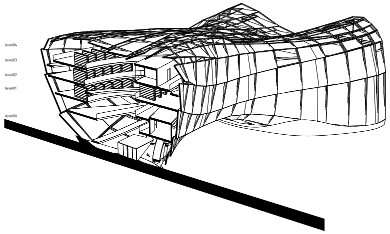
Section BB
1:300

Ill. 145

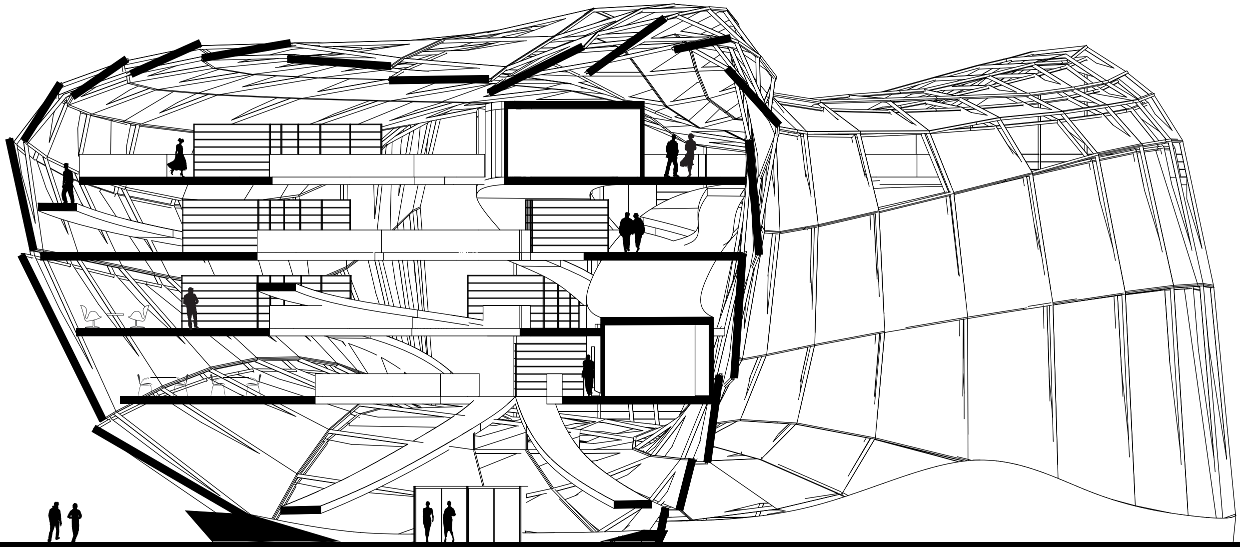




Section CC
1:300

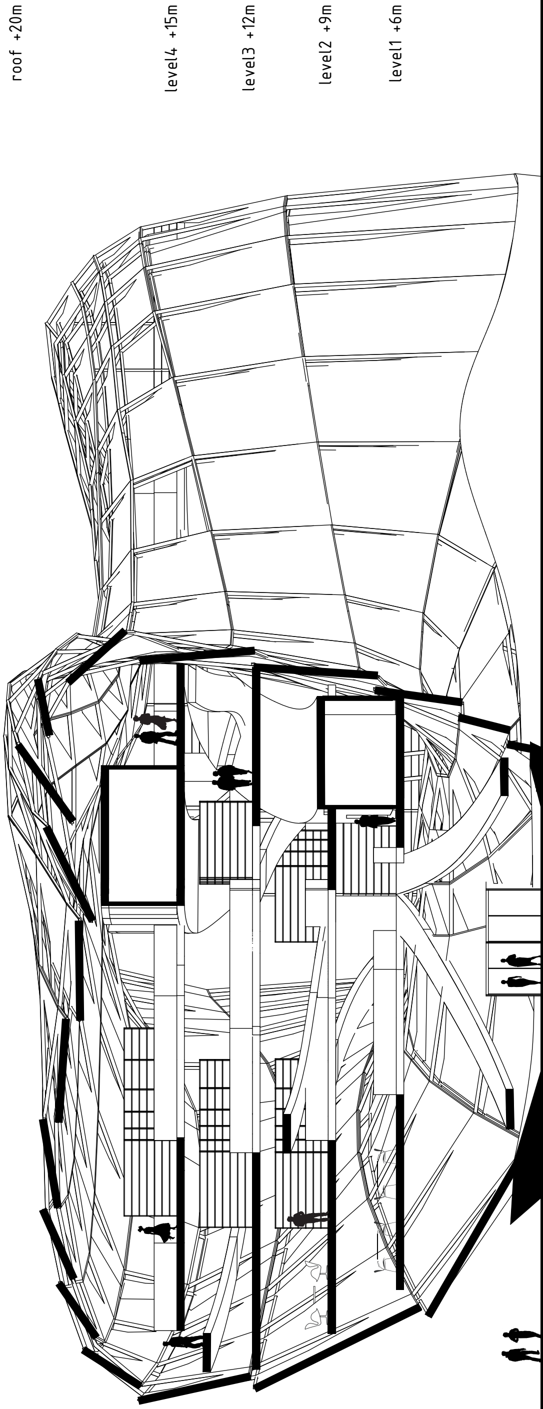


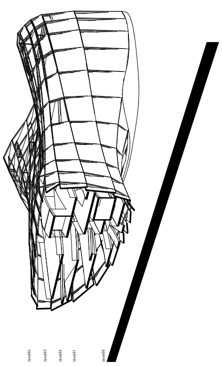
Ill. 146



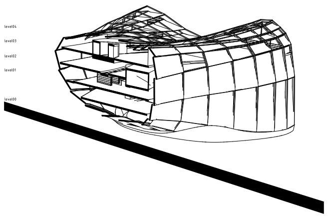
Section DD
1:300

Ill. 147

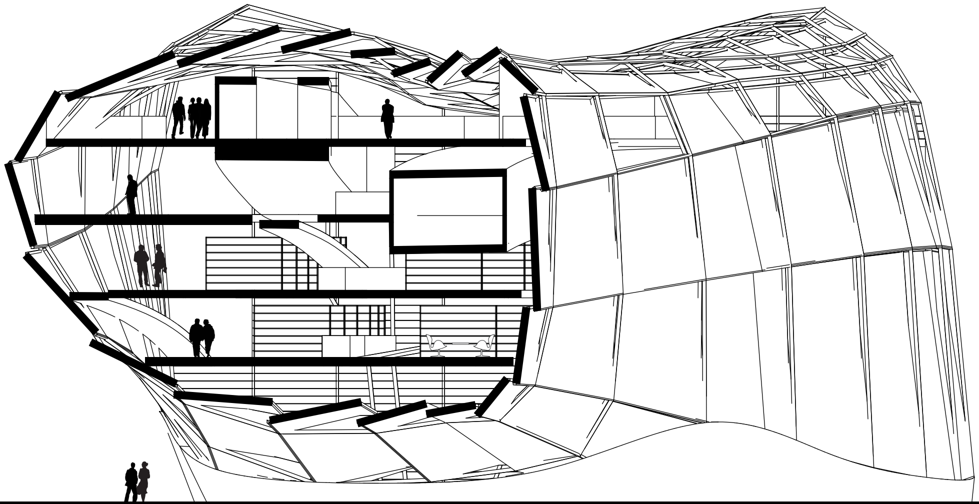




Section EE
1:300

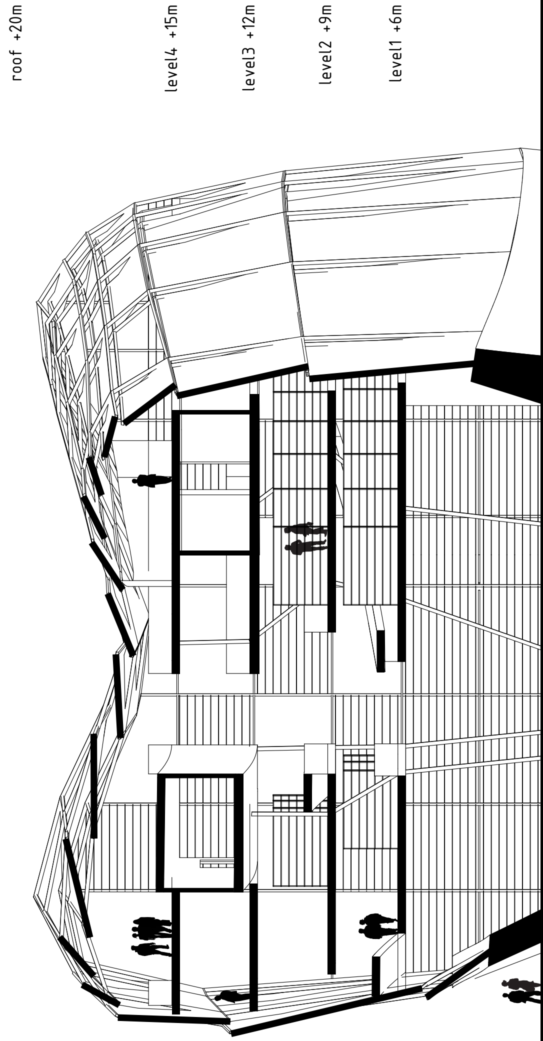


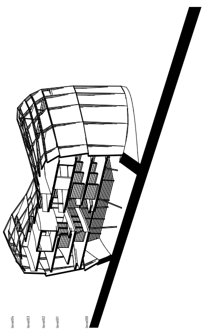
Ill. 148



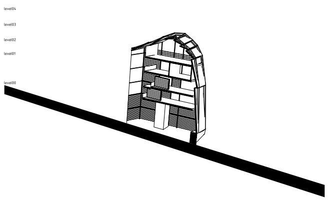
Section FF
1:300

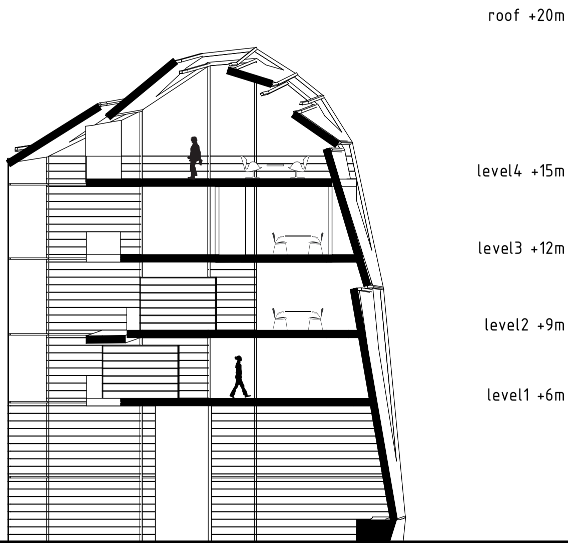
Ill. 149





Section GG
1:300



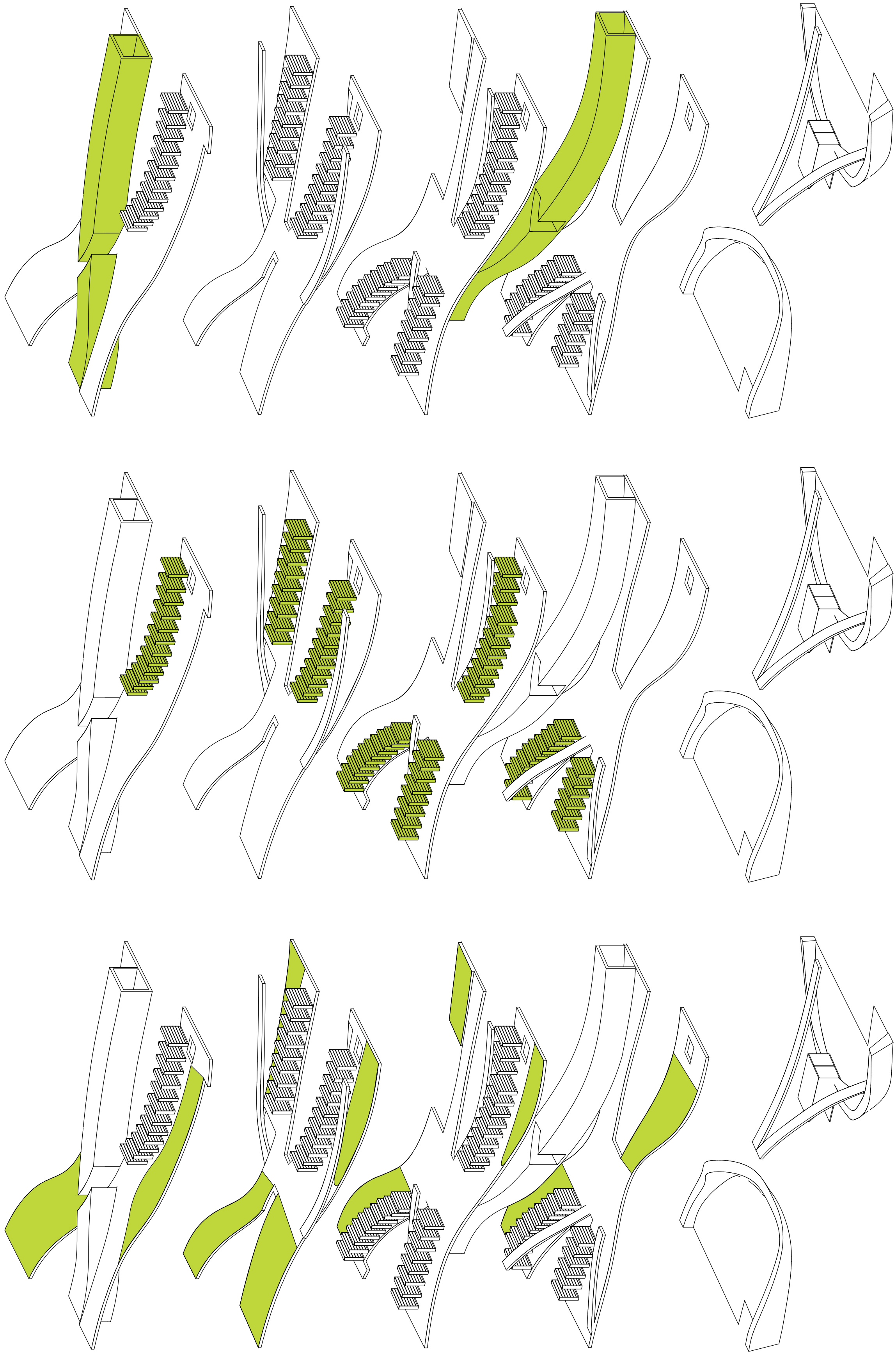


Ill. 150

Section HH
1:300

Ill. 151 *The building programme is distributed through the conceptual organisation with transformation according to parameters that have influenced a movement of programme during the process path illustrated.*

Studios, shelves and open spaces are thus organised in an organic programmatic weaving with diversity of use according to functional wishes. The house offers a series of facilities seen to accommodate contemporary and future use in a simple, yet intriguing layout.

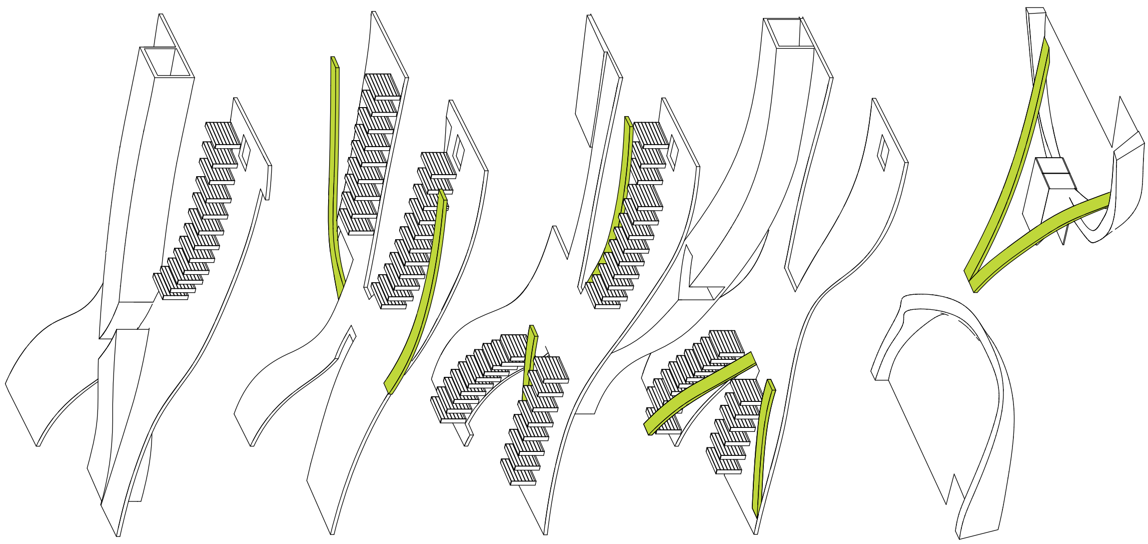


Ill. 152

A weaving layout and surrounding morphology is continued through the movement within the library, by stretching the connecting ramps from the centre of the building to the envelope. Open and enclosed spaces are created through passages moving the visitor between the inner voids from the atria to the sliced enclosure by the envelope resembling the narrow alleys of the city and the open squares.

Four transfer nodes are located on each floor, with exception of level 4, creating several possible trajectories for the visitor, depending on the material searched or desire to walk. If the latter is of non-existence, an elevator is to be found in the entrance side of the building.

Illustrated are three paths of movement from the entrance area to the café at the top. The longest path possible is of 240 meters – the shortest of 15 with the lift.



Ill. 153

A new cultural frame is designed in vibrant Raval, with focus to its inhabitants, visitors and the environmental impact it creates, merging with the local activities and the city's movement, extending the cultural offer while at the same time contrasting the existing building substance in expression and time.

The library is open and light, while maintaining enclosure and calm. It frames and divides an urban space, while improving the present circumstances for public education and cultural meeting in the city zone.

8.0 REFLECTIONS

Line of thought

The aim of the project was to describe a new approach to the development of architectural projects by a path having been described and illustrated by a limited number of currently existing examples within the built fabric and most extensively through a very own pilot project: the New Raval Library by means of identifying novel processes of design. It is an attempt to clarify possibilities within the developed framework and to create an interesting building from multiple perspectives in both presence inside and around the building and with respect to miscellaneous performative aspects.

Allowing the computer to take active part in the form-finding process naturally forces to discard traditional process paths, enforcing interaction through exploration.
Input, as described through pre-solutions, is necessary whether created as imagined through the presented material or as sole scripting strategies. An idea of designing with the computer, enlarges the elastic creative mind into new imaginative and narrative environments, as the mind must create a refined entity to compute upon. Simply, a bad script or poor designed computational entity will unavoidably create an equal bad architectural result. Architectural computation is therefore not a lonely stranger, overtaking the position of the designer, but rather an extension into other dimensions through a change in process and range of possible results.

It embraces curiosity and exploration through information as building blocks, as a fluid mass of form. It is a line of thought, which believes in designing beginnings, rather than preset formalistic expression. This binds performative computational architecture to exploration as a result of designing with information creating formation, developing form.

Downfalls of computational strategies can be seen in developed projects through generic procedures, which do not relate the tool in a critical way to an understanding of use. When no intention is put to inform intelligence, being of both aesthetical and physical performative character, into the pre-solutions or generative protocols, a proliferation of complex elements creating a contemporary baroque is the result.

Positively are improved use of digital tools rising with extension to new domains of communication and creation. A shift in thought has in some architectural fields evolved to a scientific handling and a new procedure of form finding in trial-error systems no different to the natural sciences. More presence in all architectural phases from concept to physical building is being practised through construction logic implemented into geometrical and material systems, effectively bringing the architect back to the idea of a master builder in respect to knowledge and its application, rather than the modernistic idea of the architect above all others.

Architectural branching

Recognising and using architectural differentiation, as process, described earlier might be as necessary to realise as stated in the introduction of this thesis, to shape architecture

through more directed aims, not to limit design searching, but to reach further through improved processes. Application of software as generic tool can be as devastating and inhibiting to some projects, as it can be crucial in others for realisation. It implies a certain level of complexity, not limited to complexity in form, for sincere application for improved results, rather than being an additive part in contemporary explorative architecture. Some branches of architecture are thus prone to be induced by the advancement of the digital media, to improve the defined field, as is the case with a performing architecture, e.g. sustainable architecture.

In the branching of the field lie the dangers which were tried avoided in this work through strategies framing quantifiable optimisation to social relations, described through the four operation strategies; wind, solar, material and topography. A focused strategy is in this work not seen to be limiting, but rather to construct freedom for implementation of opposing values, as the main topic is imbedded through the pre-solutions. Embracing the possibilities enabled by computation with critical respond to the created material is thus seen as highly important aspects of contemporary sustainable architecture.

A pilot

This thesis attempted the bridging of computation in digital design with sustainable design in theory and praxis, thus reaching further with combined force with the aim of clear, improved conditions for explorative sustainable architecture, tackling the severe levels of complexity presented by this type of a project, which have been explored and experienced within this pilot project.

In order to achieve a holistic measurement of environmental results, a yet even wider iterative analysis with the implementation of more specific and advanced tools and the designation of correspondingly more time is necessary. Design focus within my thesis project has been kept to the use of natural daylight and energy collection in performative and expressional spheres, to create the last verifying data. It is however important to understand that the aspects have been implemented on the design level, following the originally laid out idea, through the pre-solution strategies with respect to solar, wind and material analysis. Topography is implemented in parallel development of inner and outer spatial concepts, keeping continuous cross references to the natural forces and their site specific data.

The library is therefore seen as a representative of the framework without limiting the theoretical concepts to its formal expression. It belongs to an ongoing research, with the aim described in the beginning of this thesis, to inform formation to form. Fundamental pillars of form finding must thus be of sustainable character, rather than formalistic, to be genuinely searching for environmental performative answers.

9.0 APPENDIX

9.1 NOTES

1)
Advantages of early implementation of information has significant difference in building cost, as digital analysis and simulations predict and improve running cost though out the building life time and enables predictions of material and system failures. Adjustments can thus be applied in a fraction of time compared to rebuilding of constructed elements or completed buildings [Arup-GT, 2006].
2)
Computerization is about automation, mechanization,digitization, and conversion. Generally, it involves the digitization of entities or processes that are preconceived, predetermined, and well defined. [Terzidis, 2006]
3)
Computation is about the exploration of indeterminate, vague, unclear, and often ill-defined processes; because of its exploratory nature, computation aims at emulating or extending the human intellect. [Terzidis, 2006]
4)
NURBS (Non-Uniform-Rational-Bezier-Spline) (NURBS) is a mathematical model commonly used in computer graphics for generating and representing curves and surfaces.
[http://en.wikipedia.org/wiki/Nurbs]
5)
UV parameters: NURBS operate in Cartesian space, meaning X,Y,Z coordinates but with parametric definitions of U and V. U is a single parameter for a NURBS curve representing a location on the curve. NURBS surfaces can then be defined in UV directions within the Cartesian space. [Kolarevic, 2005]
6)
Greg Lynn defines motion-based architecture through his publication Animated Form in 1999, which describes new creative cognition, emergent digital tools and their potential based on calculus notations, philosophy and art. [Lynn, 1999]
7)
Morphogenesis: Morphogenesis (from the Greek morphê shape and genesis creation) is one of three fundamental aspects of developmental biology along with the control of cell growth and cellular differentiation. Morphogenesis is concerned with the shapes of tissues, organs and entire organisms and the positions of the various specialized cell types. Morphogenesis derives from biological terminology, meaning the origin and development of morphological characteristics. In biology morphology means the branch of biology that deals with the form of living organisms, and with relationships between their structures. [Oxford American Dictionary, 2007]
8)
A common method of translation is via an intermediary format. The sending CAD system exports out to this format and the receiving CAD system reads in this format. Some formats are independent of the CAD vendors being defined by standards organisations while others, although owned by a company, are widely used and are regarded as quasi industry standards. It is becoming increasingly common for companies owning these quasi industry stan-

dards to further the use of their formats by openly publishing these data formats. [http://en.wikipedia.org/wiki/CAD_data_exchange]
9)
Integrated processes [Knudstrup, 2007]
10)
A/E/C industry of problematic corporations (e.g. Sydney opera house) Szalapaj/Kolarevic
11)
Semantics. The branch of linguistics and logic concerned with meaning. There are a number of branches and subbranches of semantics, including formal semantics, which studies the logical aspect of meaning, such as sense, reference, application and logical form. [Oxford American Dictionary, 2007]
12)
Autistic thinking [Lawson, 2006]
13)
Reasoning: The power of the mind to think, understand, and form judgments by a process of logic. [Oxford American Dictionary, 2007]
14)
Rapid-prototyping is the automatic construction of physical objects using solid freeform fabrication. [Kolarevic, 2006]
15)
A heuristic is a method to help to solve a problem, commonly informal. It is particularly used for a method that often rapidly leads to a solution that is usually reasonably close to the best possible answer. [Shaviv et al, 2001]
16)
Procedural methods. An established or official way of doing something. [Oxford American Dictionary, 2007]
17)
Deep Knowledge describes a larger understanding of the touched subject beyond immediate heuristics [Shaviv et al, 2001]
18)
Empiricism. The theory that all knowledge is derived from sense-experience. Stimulated by the rise of experimental science. Practice based on experiment and observation. [Oxford American Dictionary, 2007]
19)
Technocrats are individuals with technical training and occupations who perceive many important societal problems as being solvable, often while proposing technological-focused solutions. [wikipedia.org/wiki/Technocrat, 2007]
20)
Being in the world, [Botin, 2005]
21)
Emergence can be related to scientific fields stretching from politics to mathematics but is based on the same definitions. A current definition of emergence is provided by Professor

Jeffrey Goldstein 1999. The arising of novel and coherent structures, patterns and properties during the process of self-organisation in complex systems. [wikipedia.org/wike/Emergence, 2007]
22)
See note 7.
23)
A phase change material (PCM) is a substance with a high heat of fusion which, melting and solidifying at a certain temperature, is capable of storing and releasing large amounts of energy. [http://en.wikipedia.org/wiki/Phase_Change_Material]
24)
PPD (Predicted Percentage Dissatisfied) [Brohus, 2006]
25)
In physics, thermal conductivity, is the property of a material that indicates its ability to conduct heat.
26)
Thermal mass, in the most general sense, is any material that has the capacity to store heat. When used correctly, it can significantly reduce the requirement for active heating and cooling systems and the consumption of active solar, renewable energy, and especially fossil fuel technologies.
27)
High CO2 levels cause headache, nausia and death if exposed in high amounts.
28)
SBS (Sick Building Syndrome). Definition from Oxford American Dictionary. A condition affecting office workers, typically marked by headaches and respiratory problems, attributed to unhealthy or stressful factors in the working environment such as poor ventilation.
29)
Stack effect is the movement of air into and out of buildings, chimneys, flue gas stacks, or other containers, and is driven by buoyancy. Buoyancy occurs due to a difference in indoor-to-outdoor air density resulting from temperature and moisture differences. The result is either a positive or negative buoyancy force. The greater the thermal difference and the height of the structure, the greater the buoyancy force, and thus the stack effect.
30)
See note 23.
31)
Maximum depth, not lower u-value [Brohus, 2006]
32)
U-value describes the properties of an element in relation to transfer of heat through the element and can be defined with the unit W/m2K. Watt is the energy, passing through a defined are m2, with the temperature difference K (Kelvin). A low u-value indicates a well-insulated material element. Some windows operate with a u-value 0.8, while many wall elements reach a u-value 0.15. [www.rockwool.dk]
33)

Generative Components can be described through a series of concepts constructed by the developer Robert Aish. 1) Implication: the ability to define "long-chain" associativity of geometric constructs, allowing the implications of change to be explored via automatic change propagation. 2) Conditional modelling: the ability to encode and exercise alternative implications allowing changes in behaviour or configuration of the geometric construct. 3) Extensibility: the ability to turn parametric models into new reusable components, where behaviour of the component is defined by the original model. 4) Components: the transition from digital components representing discrete physical entities to devices for cognitive structuring. 5) Replication: the ability to operate on sets of digital components, potentially where each set member can uniquely respond to variations in its context. 6) Programmatic design: the ability to combine declarative representations in the form of an implication structure and procedural representations. 7) Multiple representations: the ability for the user to simultaneously create and operate on different complementary, linked operations. 8) Transactional model of design: representations are an editable, re-executable design history. [Aish, 2006]
34)
Due to lack of compatability between software programmes are direct link between Ecotect and Generative Components not a possibllity at present date.

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Yu-Tung Liu and Chor-Kheng Lim, Graduate Institute of Architecture, National Chiao Tung University, Hsinchu 30050, Taiwan
New tectonics: a preliminary framework involving classic and digital thinking

Aranda/Lasch	http://www.arandalasch.com/	
Smart Geomatry	http://www.smartgeometry.com/	
Arup AGU	www.arup.com	
Paracloud	http://www.paracloud.com/	
Grimshaw	www.grimshawarchitects.com	
Buro Happold	www.burohappold.com	
Site	http://sitenewyork.com/frame/index.htm	
Smartgeometry	www.smartgeometry.com	
Generative Comp.	www.bentleysystems.com	
IPCC	www.ipcc.ch	
Wikipedia	www.wikipedia.com	(link: Passiv Haus)
		(link: Kyoto Protokol)
		(link: Case study theory)
	http://en.wikipedia.org/wiki/30_St_Mary_Axe (4th dec. 2007)	
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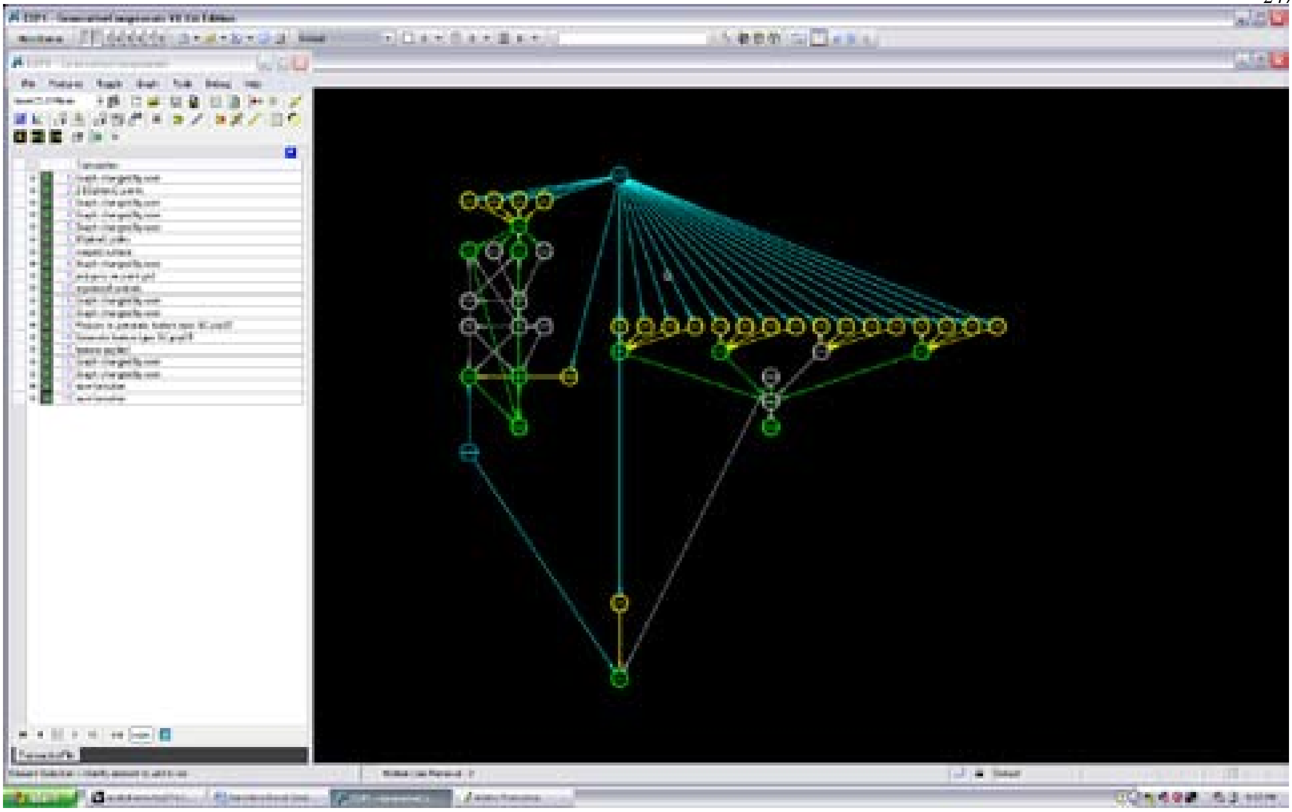
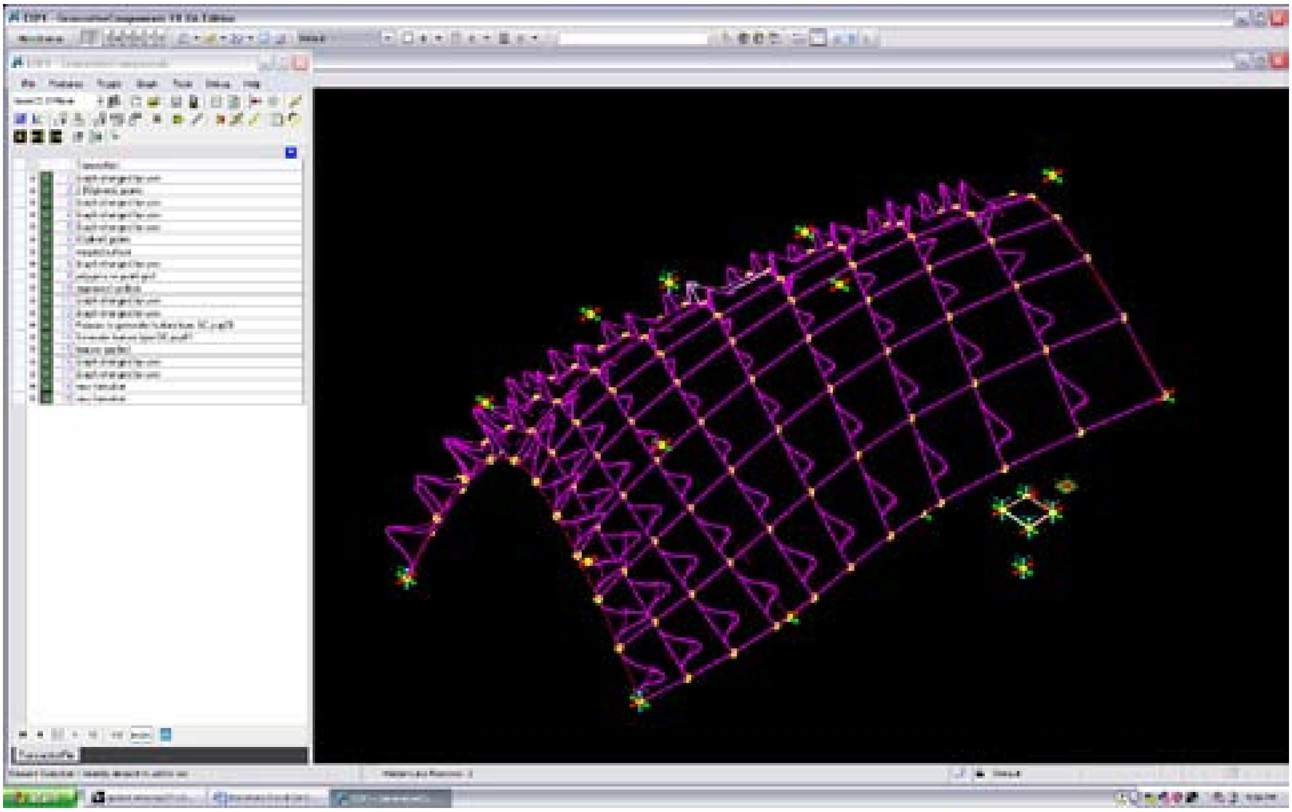
Furqan Khatri	http://archnet.org/forum/view.jsp?message_id=116917 (13/12/07, 16:15)	

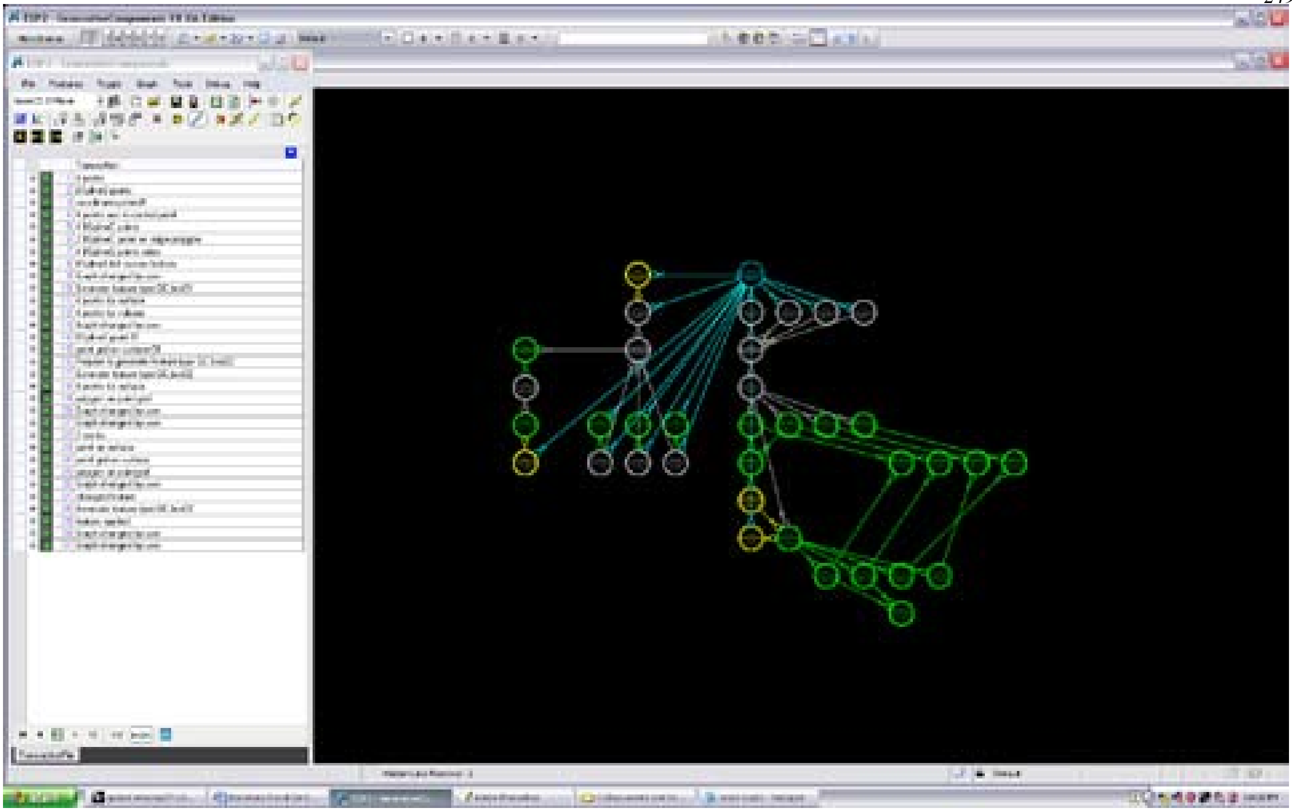
9.3 PARAMETRIC MODELS

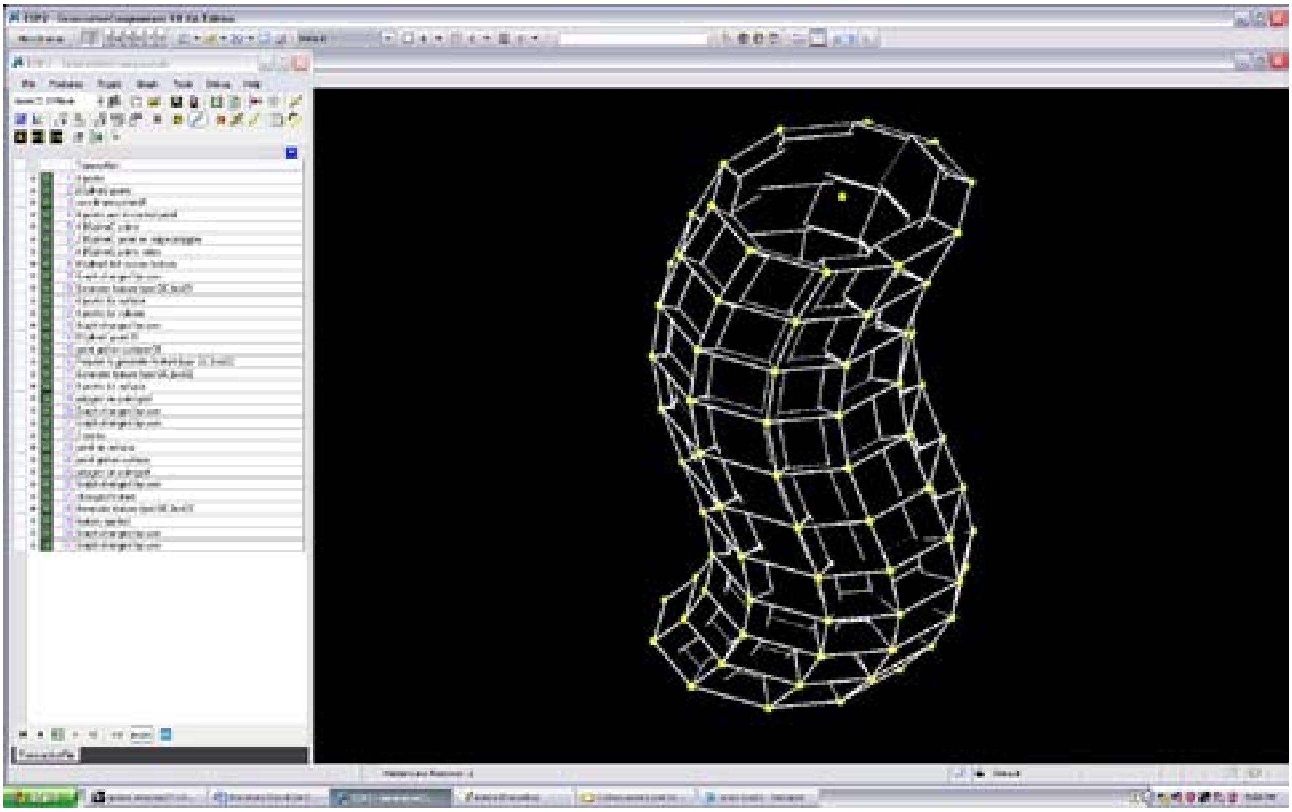
```
transaction modelBased "Graph changed by user"
{
  feature point01 GC.Point
  {
    CoordinateSystem = baseCS;
    XTranslation = <free> (-2.48226436797495);
    YTranslation = <free> (0.932265291049387);
    ZTranslation = <free> (0.0);
    HandlesVisible = true;
    Visible = false;
  }
  feature point02 GC.Point
  {
    CoordinateSystem = baseCS;
    XTranslation = <free> (-2.5368218370726);
    YTranslation = <free> (-1.36222989703381);
    ZTranslation = <free> (0.0);
    HandlesVisible = true;
    Visible = false;
  }
  feature point03 GC.Point
  {
    CoordinateSystem = baseCS;
    XTranslation = <free> (-4.695444710169);
    YTranslation = <free> (-1.46991952363898);
    ZTranslation = <free> (0.0);
    HandlesVisible = true;
    Visible = false;
  }
  feature point04 GC.Point
  {
    CoordinateSystem = baseCS;
    XTranslation = <free> (-4.50981832378209);
    YTranslation = <free> (1.00368844489613);
    ZTranslation = <free> (0.0);
    HandlesVisible = true;
    Visible = false;
  }
  feature point05 GC.Point
  {
    Curve = polygon01;
    T = 0;
    HandlesVisible = true;
    Replication = ReplicationOption.AllCombinations;
  }
  feature point06 GC.Point
  {
    Curve = polygon01;
    T = 0.25;
    HandlesVisible = true;
  }
  feature point07 GC.Point
  {
    Curve = polygon01;
    T = 0.5;
    HandlesVisible = true;
  }
  feature point08 GC.Point
  {
    Curve = polygon01;
    T = 0.75;
    HandlesVisible = true;
  }
  feature polygon01 GC.Polygon
  {
    Vertices = {point01,point02,point03,point04};
  }
}

transaction modelBased "2 BSplinesC points"
{
  deleteFeature point05;
  deleteFeature point06;
  deleteFeature point07;
  deleteFeature point08;
  feature bsplineCurve01 GC.BSplineCurve
  {
    Points = {polygon01.Vertices[0],polygon01.Vertices[1]};
    Color = 2;
  }
  feature bsplineCurve02 GC.BSplineCurve
  {
    Points = {polygon01.Vertices[3],polygon01.Vertices[2]};
    SymbolXY = {102, 103};
    SymbolicModelDisplay = null;
    Color = 2;
    FillColor = -1;
    Free = true;
    Level = 0;
    LevelName = "Default";
    LineStyle = 0;
    LineStyleName = "0";
    LineWeight = 0;
    MaximumReplication = true;
    PartFamilyName = null;
    PartName = null;
    RoleInExampleGraph = null;
    Transparency = 1;
  }
  feature point09 GC.Point
  {
    Curve = bsplineCurve01;
    T = Series(0,1,0.25);
    Color = 3;
  }
  feature point10 GC.Point
  {
    Curve = bsplineCurve02;
    T = Series(0,1,0.2);
    Color = 3;
  }
  feature polygon01 GC.Polygon
  {
    SymbolXY = {101, 102};
  }
}

transaction modelBased "Graph changed by user"
{
  feature bsplineSurface01 GC.BSplineSurface
  {
    Curves = {bsplineCurve02,bsplineCurve01};
    SymbolXY = {101, 105};
    Color = 10;
  }
}

transaction modelBased "Graph changed by user"
{
  feature bsplineCurve01 GC.BSplineCurve
  {
    SymbolXY = {100, 103};
  }
  feature bsplineCurve02 GC.BSplineCurve
  {
    SymbolXY = {102, 103};
  }
  feature bsplineSurface01 GC.BSplineSurface
  {
    SymbolXY = {101, 104};
  }
  feature point09 GC.Point
  {
    SymbolXY = {100, 104};
  }
  feature point10 GC.Point
  {
    SymbolXY = {102, 104};
  }
}

transaction modelBased "Graph changed by user"
{
  feature bsplineCurve03 GC.BSplineCurve
  {
    Poles = {point12,point13,point14,point15};
    Order = 3;
    Color = 10;
  }
  feature bsplineCurve04 GC.BSplineCurve
  {
    Poles = {point16,point17,point18,point19};
    Order = 3;
    Color = 10;
  }
  feature bsplineCurve05 GC.BSplineCurve
  {
    Poles = {point20,point21,point22,point23};
    Order = 3;
    Color = 10;
  }
  feature bsplineCurve06 GC.BSplineCurve
  {
    Poles = {point24,point25,point26,point27};
    Order = 3;
    Color = 10;
  }
  feature bsplineSurface01 GC.BSplineSurface
  {
    Color = 15;
  }
  feature bsplineSurface02 GC.BSplineSurface
  {
    Curves = {bsplineCurve03,bsplineCurve04,bsplineCurve0
5,bsplineCurve06};
    Color = 20;
  }
  feature point12 GC.Point
  {
    CoordinateSystem = baseCS;
    XTranslation = <free> (-30.0414525219926);
    YTranslation = <free> (26.7458230448181);
    ZTranslation = <free> (0.0);
    HandlesVisible = true;
  }
  feature point13 GC.Point
  {
    CoordinateSystem = baseCS;
    XTranslation = <free> (-28.7920409655628);
    YTranslation = <free> (21.2300802147865);
    ZTranslation = <free> (0.0);
    HandlesVisible = true;
  }
  feature point14 GC.Point
  {
    CoordinateSystem = baseCS;
    XTranslation = <free> (-31.18674644872);
    YTranslation = <free> (15.6102667653203);
    ZTranslation = <free> (0.0);
    HandlesVisible = true;
  }
  feature point15 GC.Point
  {
    CoordinateSystem = baseCS;
    XTranslation = <free> (-28.5838057061578);
    YTranslation = <free> (8.11718216603201);
    ZTranslation = <free> (0.0);
    HandlesVisible = true;
  }
  feature point16 GC.Point
  {
    CoordinateSystem = baseCS;
    XTranslation = <free> (-20.3585129596611);
    YTranslation = <free> (27.3702467614254);
    ZTranslation = <free> (0.0);
    HandlesVisible = true;
  }
  feature point17 GC.Point
  {
    CoordinateSystem = baseCS;
    XTranslation = <free> (-17.6514545873964);
    YTranslation = <free> (23.3114926034776);
    ZTranslation = <free> (0.0);
    HandlesVisible = true;
  }
  feature point18 GC.Point
  {
    CoordinateSystem = baseCS;
    XTranslation = <free> (-19.3173366626362);
    YTranslation = <free> (15.5061961458857);
    ZTranslation = <free> (0.0);
    HandlesVisible = true;
  }
  feature point19 GC.Point
  {
    CoordinateSystem = baseCS;
    XTranslation = <free> (-15.8814548824541);
    YTranslation = <free> (8.01311154659745);
    ZTranslation = <free> (0.0);
    HandlesVisible = true;
  }
  feature point20 GC.Point
  {
    CoordinateSystem = baseCS;
    XTranslation = <free> (-6.1985153201226);
    YTranslation = <free> (27.0580349031218);
    ZTranslation = <free> (0.0);
    HandlesVisible = true;
  }
  feature point21 GC.Point
  {
    CoordinateSystem = baseCS;
    XTranslation = <free> (-2.34616302113049);
    YTranslation = <free> (20.1893740204409);
    ZTranslation = <free> (0.0);
    HandlesVisible = true;
  }
  feature point22 GC.Point
  {
    CoordinateSystem = baseCS;
    XTranslation = <free> (-4.74086850428775);
    YTranslation = <free> (14.7777018098438);
    ZTranslation = <free> (0.0);
    HandlesVisible = true;
  }
  feature point23 GC.Point
  {
    CoordinateSystem = baseCS;
    XTranslation = <free> (-2.45028065083299);
    YTranslation = <free> (9.99045331585407);
    ZTranslation = <free> (0.0);
    HandlesVisible = true;
  }
  feature point24 GC.Point
  {
    CoordinateSystem = baseCS;
    XTranslation = <free> (9.00265861644083);
    YTranslation = <free> (27.9946704780328);
    ZTranslation = <free> (0.0);
    HandlesVisible = true;
  }
  feature point25 GC.Point
  {
    CoordinateSystem = baseCS;
    XTranslation = <free> (15.5620692876977);
    YTranslation = <free> (21.6463626925247);
    ZTranslation = <free> (0.0);
    HandlesVisible = true;
  }
  feature point26 GC.Point
  {
    CoordinateSystem = baseCS;
    XTranslation = <free> (12.5426580263255);
    YTranslation = <free> (13.7369956154982);
    ZTranslation = <free> (0.0);
    HandlesVisible = true;
  }
  feature point27 GC.Point
  {
    CoordinateSystem = baseCS;
    XTranslation = <free> (16.8114808441275);
    YTranslation = <free> (8.32532340490113);
    ZTranslation = <free> (0.0);
    HandlesVisible = true;
  }
}

transaction modelBased "BSplineS poles"
{
  feature point25 GC.Point
  {
    XTranslation = <free> (16.0633763936725);
    YTranslation = <free> (24.0900950155437);
  }
}

transaction modelBased "warped surface"
{
  feature point11 GC.Point
  {
    Surface = bsplineSurface02;
    U = Series(0,1,0.1);
    V = Series(0,1,0.1);
    SymbolXY = {100, 112};
    Color = 0;
    FillColor = -1;
    Free = true;
    HandlesVisible = true;
    IsModifiable = false;
    Level = 0;
    LevelName = "Default";
    LineStyle = 0;
    LineStyleName = "0";
    LineWeight = 0;
    MaximumReplication = true;
    Replication = ReplicationOption.AllCombinations;
    SymbologyAndLevelUsage = SymbologyAndLevelUsageOp-
tion.AssignToFeature;
    Transparency = 1;
  }
  feature point12 GC.Point
  {
    ZTranslation = <free> (-5.20273057042466);
  }
  feature point15 GC.Point
  {
    ZTranslation = <free> (-5.79301176348074);
  }
  feature point21 GC.Point
  {
    ZTranslation = <free> (-5.48296492502435);
  }
  feature point24 GC.Point
  {
    ZTranslation = <free> (-1.73216317736347);
  }
  feature point27 GC.Point
  {
    ZTranslation = <free> (-4.82826516630106);
  }
}

transaction modelBased "Graph changed by user"
{
  feature bsplineSurface02 GC.BSplineSurface
  {
    SymbolXY = {106, 109};
  }
  feature point11 GC.Point
  {
    SymbolXY = {106, 110};
  }
}

transaction modelBased "polygons on point grid"
{
  feature polygon02 GC.Polygon
  {
    Points = point11;
  }
}

transaction modelBased "organised symbols"
{
  feature bsplineCurve01 GC.BSplineCurve
  {
    SymbolXY = {95, 103};
  }
  feature bsplineCurve02 GC.BSplineCurve
  {
    SymbolXY = {97, 103};
  }
  feature bsplineSurface01 GC.BSplineSurface
  {
    SymbolXY = {96, 105};
  }
  feature point01 GC.Point
  {
    SymbolXY = {94, 101};
  }
  feature point02 GC.Point
  {
    SymbolXY = {95, 101};
  }
  feature point03 GC.Point
  {
    SymbolXY = {96, 101};
  }
  feature point04 GC.Point
  {
    SymbolXY = {97, 101};
  }
  feature point09 GC.Point
  {
    SymbolXY = {95, 104};
  }
  feature point10 GC.Point
  {
    SymbolXY = {97, 104};
  }
  feature polygon01 GC.Polygon
  {
    SymbolXY = {96, 102};
  }
}

transaction modelBased "Graph changed by user"
{
  deleteFeature point09;
  deleteFeature point10;
  feature coordinateSystem01 GC.CoordinateSystem
  {
    Surface = bsplineSurface01;
    U = <free>
(0.490729947053543);
    V = <free>
(0.300958170445096);
    HandlesVisible = true;
  }
  feature point28 GC.Point
  {
    Surface = bsplineSurface01;
    U = Series(0,1,0.25);
    V = Series(0,1,0.5);
    SymbolXY = {96, 106};
    Color = 0;
    FillColor = -1;
    Free = true;
    HandlesVisible = true;
    IsModifiable = false;
    Level = 0;
    LevelName = "Default";
    LineStyle = 0;
    LineStyleName = "0";
    LineWeight = 0;
    MaximumReplication = true;
    Replication = ReplicationOption.
AllCombinations;
    SymbologyAndLevelUsage = Symbolog-
yAndLevelUsageOption.AssignToFeature;
    Transparency = 1;
  }
  feature point29 GC.Point
  {
    Origin = point28[2][2];
    Direction = coordinateSystem01.
ZDirection;
    DistanceFromOrigin = polygon01.
Length/20;
    SymbolXY = {100, 114};
    Color = 0;
    FillColor = -1;
    Free = true;
    Level = 0;
    LevelName = "Default";
    LineStyle = 0;
    LineStyleName = "0";
    LineWeight = 0;
    MaximumReplication = true;
    SymbologyAndLevelUsage = Symbolog-
yAndLevelUsageOption.AssignToFeature;
    Transparency = 1;
  }
  feature point30 GC.Point
  {
    Origin = point28[3][2];
    Direction = coordinateSystem01.
ZDirection;
    DistanceFromOrigin = polygon01.
Length/40;
    ComputeGeometryInParameterSpace = null;
    SymbolXY = {101, 114};
    SymbolicModelDisplay = null;
    Color = 0;
    FillColor = -1;
    Free = true;
    Level = 0;
    LevelName = "Default";
    LineStyle = 0;
    LineStyleName = "0";
    LineWeight = 0;
    MaximumReplication = true;
    PartFamilyName = null;
    PartName = null;
    RoleInExampleGraph = null;
    SymbologyAndLevelUsage = Symbolog-
yAndLevelUsageOption.AssignToFeature;
    Transparency = 1;
  }
  feature point31 GC.Point
```



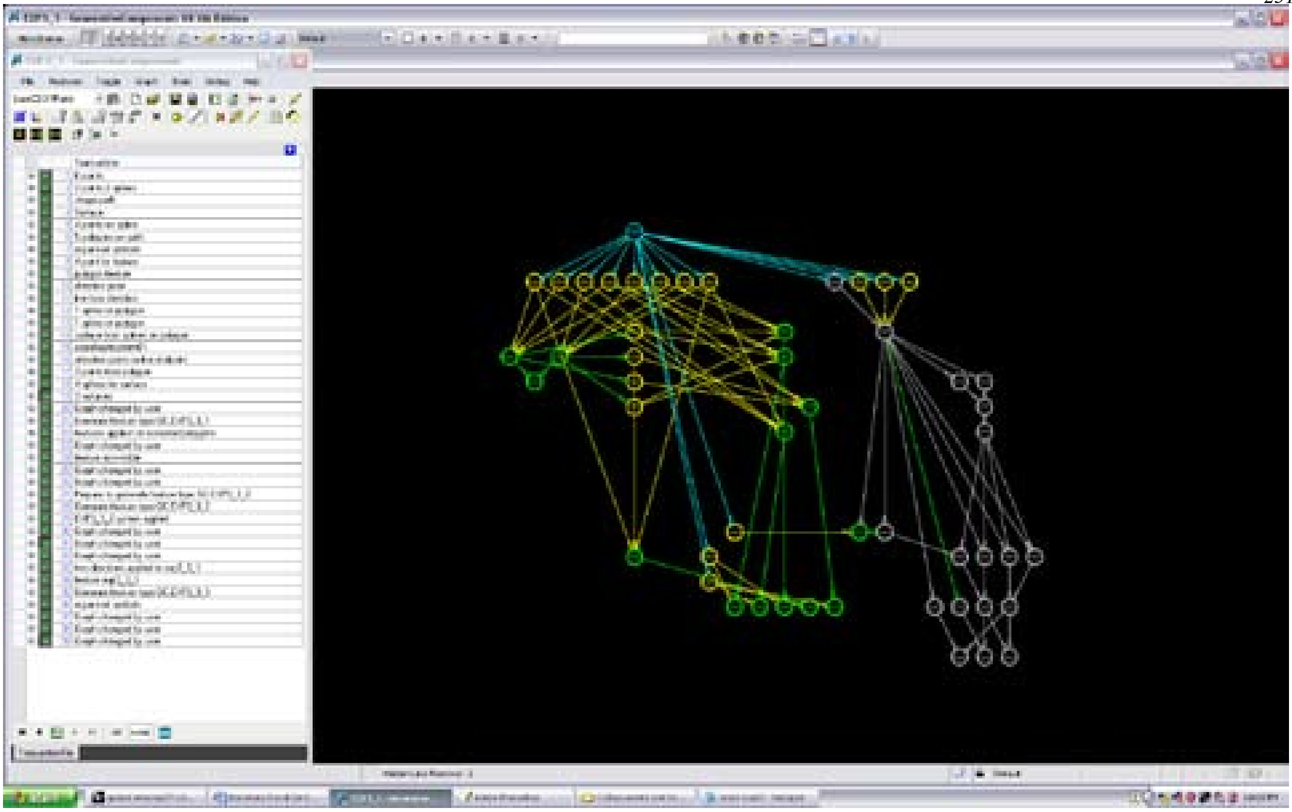


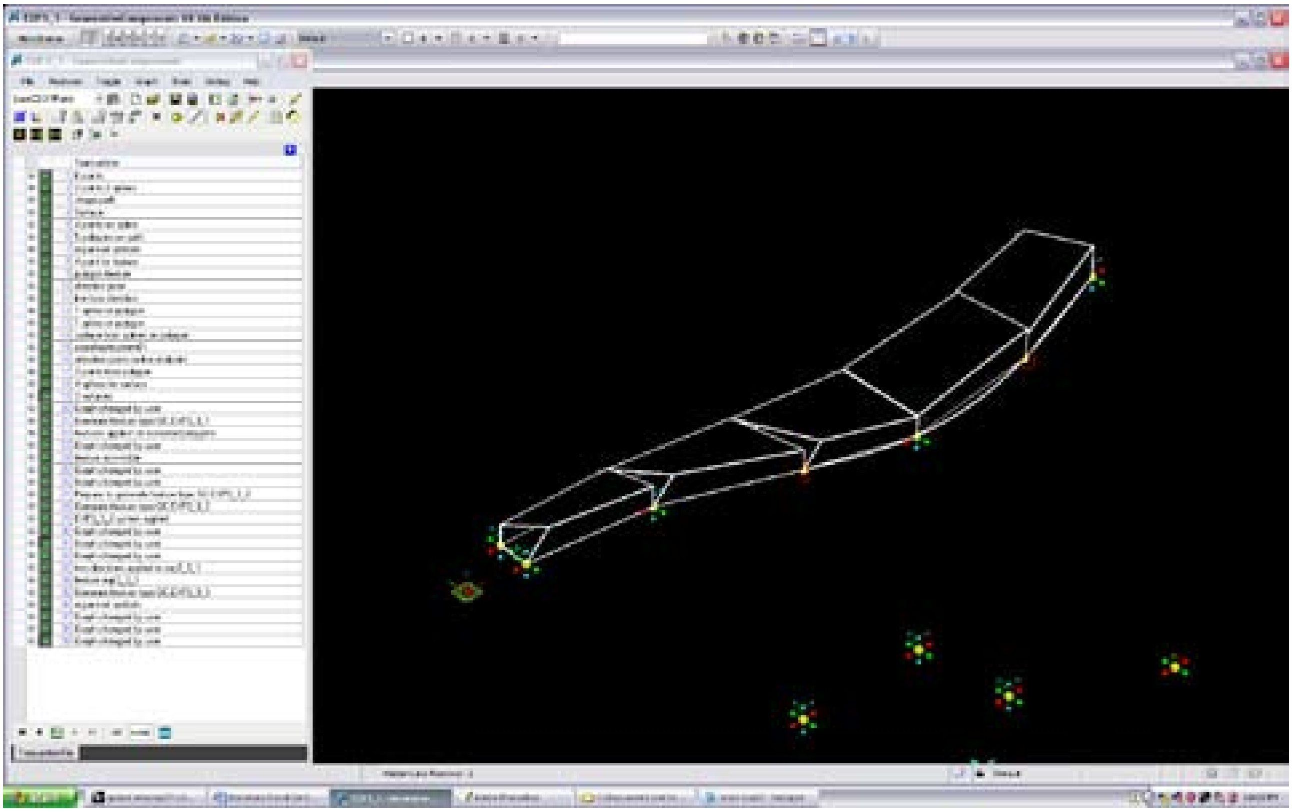
```
transaction modelBased "4 points"
{
   feature point01 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (1.81482659154812);
      YTranslation             = <free> (1.59656188164802);
      ZTranslation             = <free> (0.0);
      HandlesVisible           = true;
   }
   feature point02 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (3.40363971315875);
      YTranslation             = <free> (1.59656188164802);
      ZTranslation             = <free> (0.0);
      HandlesVisible           = true;
   }
   feature point03 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (3.37624638347581);
      YTranslation             = <free> (0.0627284024295987);
      ZTranslation             = <free> (0.0);
      HandlesVisible           = true;
   }
   feature point04 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (1.77373659702371);
      YTranslation             = <free> (0.0353385188721266);
      ZTranslation             = <free> (0.0);
      HandlesVisible           = true;
   }
}

transaction modelBased "BSplineS points"
{
   feature bsplineCurve01 GC.BSplineCurve
   {
      Points                   = {point05[0],point05[1]};
   }
   feature bsplineCurve02 GC.BSplineCurve
   {
      Points                   = {point05[3],point05[2]};
   }
   feature bsplineSurface01 GC.BSplineSurface
   {
      Curves                   = {bsplineCurve01,bsplineCurve02};
   }
   feature point01 GC.Point
   {
      Visible                  = false;
   }
   feature point02 GC.Point
   {
      Visible                  = false;
   }
   feature point03 GC.Point
   {
      Visible                  = false;
   }
   feature point04 GC.Point
   {
      Visible                  = false;
   }
   feature point05 GC.Point
   {
      Curve                    = polygon01;
      T                        = Series(0,1,0.25);
      HandlesVisible           = true;
   }
   feature polygon01 GC.Polygon
   {
      Vertices                 = {point04,point01,point02,point03};
   }
}

transaction modelBased "coordinatesystem01"
{
   feature coordinateSystem01 GC.CoordinateSystem
   {
      Surface                  = bsplineSurface01;
      U                        = <free> (0.388135251601744);
      V                        = <free> (0.333379100465456);
      HandlesVisible           = true;
   }
}

transaction modelBased "4 points acc to control point"
{
   feature point06 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (2.15813982158586);
      YTranslation             = <free> (-4.38102897896809);
      ZTranslation             = <free> (2.24046852458099);
      HandlesVisible           = true;
   }
   feature point08 GC.Point
   {
      Origin                   = point05;
      Direction                = coordinateSystem01.ZDirection;
      DistanceFromOrigin       = Distance(point06,coordinateSystem01)/10;
   }
}

transaction modelBased "4 BSplineC points"
{
   feature bsplineCurve03 GC.BSplineCurve
   {
      Points                   = {point08[0],point08[3]};
   }
   feature bsplineCurve04 GC.BSplineCurve
   {
      Points                   = {point08[1],point08[2]};
   }
   feature bsplineCurve05 GC.BSplineCurve
   {
      Points                   = {point08[0],point08[1]};
   }
   feature bsplineCurve06 GC.BSplineCurve
   {
      Points                   = {point08[3],point08[2]};
   }
}

transaction modelBased "2 BSplineC point on origin polygon"
{
   feature bsplineCurve03 GC.BSplineCurve
   {
      SymbolXY                 = {104, 108};
   }
   feature bsplineCurve04 GC.BSplineCurve
   {
      SymbolXY                 = {105, 108};
   }
   feature bsplineCurve07 GC.BSplineCurve
   {
      Points                   = {point05[1],point05[2]};
      SymbolXY                 = {102, 104};
   }
   feature bsplineCurve08 GC.BSplineCurve
   {
      Points                   = {point05[0],point05[3]};
      SymbolXY                 = {103, 104};
   }
   feature point06 GC.Point
   {
      XTranslation             = <free> (3.09471769503333);
      YTranslation             = <free> (-3.27078334138376);
   }
}

transaction modelBased "4 BSplineS points sides"
{
   feature bsplineSurface02 GC.BSplineSurface
   {
      Curves                   = {bsplineCurve05,bsplineCurve01};
      SymbolXY                 = {104, 105};
   }
   feature bsplineSurface03 GC.BSplineSurface
   {
      Curves                   = {bsplineCurve03,bsplineCurve08};
      SymbolXY                 = {107, 104};
   }
   feature bsplineSurface04 GC.BSplineSurface
   {
      Curves                   = {bsplineCurve06,bsplineCurve02};
   }
   feature bsplineSurface05 GC.BSplineSurface
   {
      Curves                   = {bsplineCurve04,bsplineCurve07};
   }
}

transaction modelBased "BSplineS loft curves bottom"
{
   feature bsplineSurface01 GC.BSplineSurface
   {
      Visible                  = false;
   }
   feature bsplineSurface06 GC.BSplineSurface
   {
      Curves                   = {bsplineCurve05,bsplineCurve06};
   }
   feature coordinateSystem01 GC.CoordinateSystem
   {
      Visible                  = false;
   }
   feature point06 GC.Point
   {
      XTranslation             = <free> (2.59034502459564);
      YTranslation             = <free> (-3.11664027601881);
   }
}

transaction modelBased "Graph changed by user"
{
   feature bsplineSurface03 GC.BSplineSurface
   {
      SymbolXY                 = {107, 105};
   }
   feature bsplineSurface04 GC.BSplineSurface
   {
      SymbolXY                 = {105, 105};
   }
   feature bsplineSurface05 GC.BSplineSurface
   {
      SymbolXY                 = {106, 105};
   }
}

transaction generateFeatureType "Generate feature type GC.box01"
{
   type                        = GC.box01;
   inputProperties             = {
                     property double coordinateSystem01_U
                     {
                        originalName       = coordinateSystem01_U;
                        isOptional         = true;
                        defaultValue       = 0.388135251601744;
                     }
                     property double coordinateSystem01_V
                     {
                        originalName       = coordinateSystem01_V;
                        isOptional         = true;
                        defaultValue       = 0.333379100465456;
                     }
                     property GC.IPoint point06
                     {
                        feature            = point06;
                     }
                     property GC.Polygon polygon01
                     {
                        feature            = polygon01;
                        isReplicatable     = true;
                        isParentModel      = true;
                     }
                  };
   outputProperties            = {
                     property GC.BSplineCurve bsplineCurve01
                     {
                        feature            = bsplineCurve01;
                        isDynamic          = true;
                     }
                     property GC.BSplineCurve bsplineCurve02
                     {
                        feature            = bsplineCurve02;
                        isDynamic          = true;
                     }
                     property GC.BSplineCurve bsplineCurve03
                     {
                        feature            = bsplineCurve03;
                        isDynamic          = true;
                     }
                     property GC.BSplineCurve bsplineCurve04
                     {
                        feature            = bsplineCurve04;
                        isDynamic          = true;
                     }
                     property GC.BSplineCurve bsplineCurve05
                     {
                        feature            = bsplineCurve05;
                        isDynamic          = true;
                     }
                     property GC.BSplineCurve bsplineCurve06
                     {
                        feature            = bsplineCurve06;
                        isDynamic          = true;
                     }
                     property GC.BSplineCurve bsplineCurve07
                     {
                        feature            = bsplineCurve07;
                        isDynamic          = true;
                     }
                     property GC.BSplineCurve bsplineCurve08
                     {
                        feature            = bsplineCurve08;
                        isDynamic          = true;
                     }
                     property GC.BSplineSurface bsplineSurface02
                     {
                        feature            = bsplineSurface02;
                        isConstruction     = true;
                        isDynamic          = true;
                     }
                     property GC.BSplineSurface bsplineSurface03
                     {
                        feature            = bsplineSurface03;
                        isConstruction     = true;
                        isDynamic          = true;
                     }
                     property GC.BSplineSurface bsplineSurface04
                     {
                        feature            = bsplineSurface04;
                        isConstruction     = true;
                        isDynamic          = true;
                     }
                     property GC.BSplineSurface bsplineSurface05
                     {
                        feature            = bsplineSurface05;
                        isConstruction     = true;
                        isDynamic          = true;
                     }
                     property GC.BSplineSurface bsplineSurface06
                     {
                        feature            = bsplineSurface06;
                        isConstruction     = true;
                        isDynamic          = true;
                     }
                     property GC.Point point05
                     {
                        feature            = point05;
                        isDynamic          = true;
                     }
                     property GC.Point point08
                     {
                        feature            = point08;
                        isDynamic          = true;
                     }
                  };
   internalProperties          = {
                     property GC.BSplineSurface bsplineSurface01
                     {
                        feature            = bsplineSurface01;
                        isDynamic          = true;
                     }
                     property GC.CoordinateSystem coordinate-
System01
                     {
                        feature            = coordinateSystem01;
                        isDynamic          = true;
                     }
                  };
}

transaction modelBased "4 points for surface"
{
   feature point07 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (10);
      YTranslation             = <free> (0);
      ZTranslation             = <free> (0.0);
      HandlesVisible           = true;
   }
   feature point09 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (10);
      YTranslation             = <free> (20);
      ZTranslation             = <free> (0.0);
      HandlesVisible           = true;
   }
   feature point10 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (10);
      YTranslation             = <free> (20);
      ZTranslation             = <free> (10);
      HandlesVisible           = true;
   }
   feature point11 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (10);
      YTranslation             = <free> (0);
      ZTranslation             = <free> (10);
      HandlesVisible           = true;
   }
}

transaction modelBased "4 points for volume"
{
   feature point12 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (20);
      YTranslation             = <free> (0);
      ZTranslation             = <free> (0.0);
      HandlesVisible           = true;
   }
   feature point13 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (20);
      YTranslation             = <free> (20);
      ZTranslation             = <free> (0.0);
      HandlesVisible           = true;
   }
   feature point14 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (20);
      YTranslation             = <free> (20);
      ZTranslation             = <free> (10);
      HandlesVisible           = true;
   }
   feature point15 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (20);
      YTranslation             = <free> (0);
      ZTranslation             = <free> (10);
      HandlesVisible           = true;
   }
}

transaction modelBased "Graph changed by user"
{
   feature point07 GC.Point
   {
      SymbolXY                 = {91, 101};
   }
   feature point09 GC.Point
   {
      SymbolXY                 = {92, 101};
   }
   feature point10 GC.Point
   {
      SymbolXY                 = {93, 101};
   }
   feature point11 GC.Point
   {
      SymbolXY                 = {94, 101};
   }
   feature point12 GC.Point
   {
      SymbolXY                 = {95, 101};
   }
   feature point13 GC.Point
   {
      SymbolXY                 = {96, 101};
   }
   feature point14 GC.Point
   {
      SymbolXY                 = {97, 101};
   }
   feature point15 GC.Point
   {
      SymbolXY                 = {98, 101};
   }
}

transaction modelBased "BSplineS point 01"
{
   feature bsplineCurve09 GC.BSplineCurve
   {
      Points                   = {point07,point11};
      SymbolXY                 = {92, 103};
   }
   feature bsplineCurve10 GC.BSplineCurve
   {
      Points                   = {point09,point10};
      SymbolXY                 = {93, 103};
   }
   feature bsplineSurface07 GC.BSplineSurface
   {
      Curves                   = {bsplineCurve09,bsplineCurve10};
      SymbolXY                 = {92, 104};
   }
}

transaction modelBased "point grid on surface 01"
{
   feature point16 GC.Point
   {
      Surface                  = bsplineSurface07;
      U                        = Series(0,1,0.2);
      V                        = Series(0,1,0.2);
      HandlesVisible           = true;
      Replication              = ReplicationOption.AllCombinations;
   }
}

transaction modelBased "Prepare to generate feature type GC.box02"
{
   feature box0101 GC.box01
   {
      point06                  = point17;
      polygon01                = polygon02;
   }
   feature bsplineCurve01 GC.BSplineCurve
   {
      Visible                  = false;
   }
   feature bsplineCurve02 GC.BSplineCurve
   {
      Visible                  = false;
   }
   feature bsplineCurve07 GC.BSplineCurve
   {
      Visible                  = false;
   }
   feature bsplineCurve08 GC.BSplineCurve
   {
      Visible                  = false;
   }
   feature bsplineSurface01 GC.BSplineSurface
   {
      Visible                  = true;
   }
   feature coordinateSystem01 GC.CoordinateSystem
   {
      Visible                  = true;
   }
   feature point05 GC.Point
   {
      Visible                  = false;
   }
   feature point16 GC.Point
   {
      SymbolXY                 = {92, 105};
   }
   feature point17 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (8.34142828273919);
      YTranslation             = <free> (23.2588922478415);
```



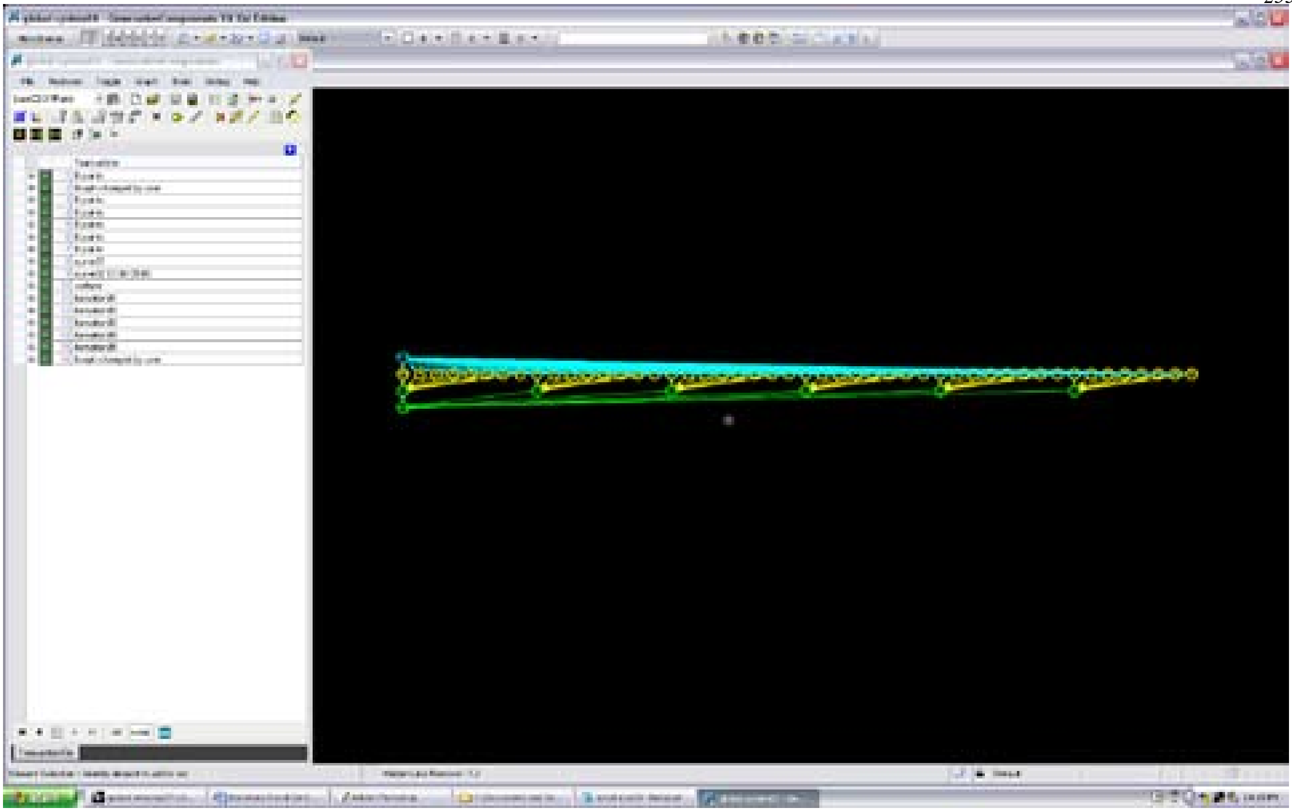


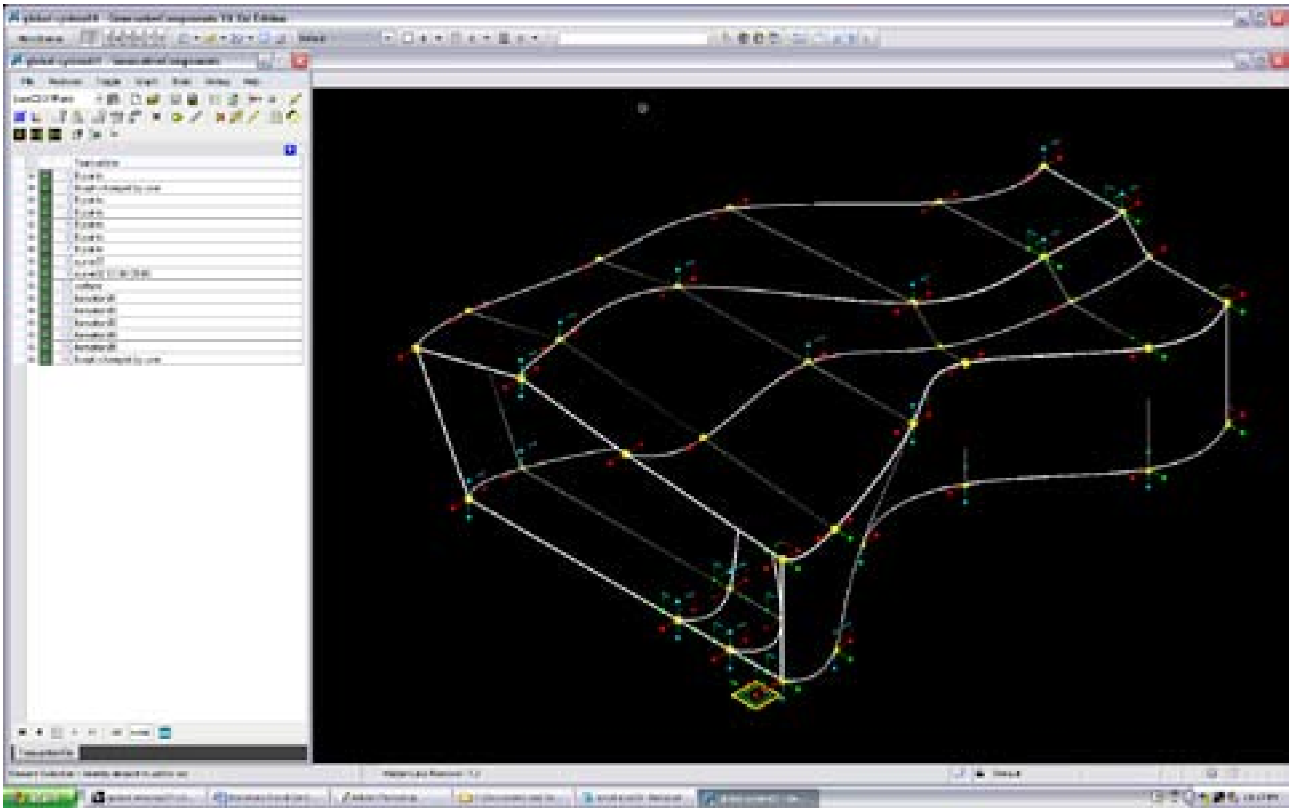
```
transaction modelBased "6 points"
{
   feature point01 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (3.27570064636659);
      YTranslation             = <free> (1.34496221671452);
      ZTranslation             = <free> (0.0);
      HandlesVisible           = true;
   }
   feature point02 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (3.32230116784648);
      YTranslation             = <free> (-1.96328768737373);
      ZTranslation             = <free> (0.0);
      HandlesVisible           = true;
   }
   feature point03 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (15.8578414459379);
      YTranslation             = <free> (0.0868953517795773);
      ZTranslation             = <free> (0.0);
      HandlesVisible           = true;
   }
   feature point04 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (15.8578414459379);
      YTranslation             = <free> (-7.25182802700774);
      ZTranslation             = <free> (0.0);
      HandlesVisible           = true;
   }
   feature point05 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (32.9485826986889);
      YTranslation             = <free> (0.92560659506956);
      ZTranslation             = <free> (0.0);
      HandlesVisible           = true;
   }
   feature point06 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (33.2631362186782);
      YTranslation             = <free> (-4.63085539172655);
      ZTranslation             = <free> (0.0);
      HandlesVisible           = true;
   }
}

transaction modelBased "2 points 2 splines"
{
   feature bsplineCurve01 GC.BSplineCurve
   {
      Points                   = {point01,point08,point03,point05};
   }
   feature bsplineCurve02 GC.BSplineCurve
   {
      Points                   = {point02,point07,point04,point06};
   }
   feature point07 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (8.89106348469379);
      YTranslation             = <free> (-3.24465208684452);
      ZTranslation             = <free> (0.0);
      HandlesVisible           = true;
   }
   feature point08 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (9.17066661357315);
      YTranslation             = <free> (0.459655904352889);
      ZTranslation             = <free> (0.0);
      HandlesVisible           = true;
   }
}

transaction modelBased "shape path"
{
   feature baseCS GC.CoordinateSystem
   {
      SymbolXY                 = {103, 99};
   }
   feature bsplineCurve01 GC.BSplineCurve
   {
      SymbolXY                 = {102, 103};
   }
   feature bsplineCurve02 GC.BSplineCurve
   {
      SymbolXY                 = {104, 103};
   }
   feature point02 GC.Point
   {
      XTranslation             = <free> (3.08929856044702);
      YTranslation             = <free> (-0.309162735329632);
   }
   feature point03 GC.Point
   {
      XTranslation             = <free> (20.4945933331873);
      YTranslation             = <free> (-1.05468384047628);
      ZTranslation             = <free> (0.349999999999692);
   }
   feature point04 GC.Point
   {
      XTranslation             = <free> (20.6809954191069);
      YTranslation             = <free> (-5.15504991878285);
   }
   feature point06 GC.Point
   {
      YTranslation             = <free> (-2.61561865437704);
      ZTranslation             = <free> (0.349999999999681);
   }
   feature point07 GC.Point
   {
      XTranslation             = <free> (11.0812879942488);
      YTranslation             = <free> (-1.33425425490627);
   }
   feature point08 GC.Point
   {
      YTranslation             = <free> (1.08868933682037);
      SymbolXY                 = {99, 101};
   }
}

transaction modelBased "Surface"
{
   feature bsplineSurface01 GC.BSplineSurface
   {
      Curves                   = {bsplineCurve02,bsplineCurve01};
   }
}

transaction modelBased "4 points on spline"
{
   feature bsplineSurface01 GC.BSplineSurface
   {
      SymbolXY                 = {103, 104};
   }
   feature point09 GC.Point
   {
      Curve                    = bsplineCurve02;
      T                        = <free> (0.420407479485306);
      HandlesVisible           = true;
   }
   feature point10 GC.Point
   {
      Curve                    = bsplineCurve02;
      T                        = <free> (0.812270418891699);
      HandlesVisible           = true;
   }
   feature point11 GC.Point
   {
      Curve                    = bsplineCurve01;
      T                        = <free> (0.394508012142373);
      HandlesVisible           = true;
   }
   feature point12 GC.Point
   {
      Curve                    = bsplineCurve01;
      T                        = <free> (0.824869303290835);
      HandlesVisible           = true;
   }
}

transaction modelBased "5 polygons on path"
{
   feature bsplineCurve01 GC.BSplineCurve
   {
      Visible                  = false;
   }
   feature bsplineCurve02 GC.BSplineCurve
   {
      Visible                  = false;
   }
   feature bsplineSurface01 GC.BSplineSurface
   {
      Visible                  = false;
   }
   feature point07 GC.Point
   {
      XTranslation             = <free> (9.58230455331232);
      YTranslation             = <free> (-1.11681059923868);
   }
   feature point10 GC.Point
   {
      SymbolXY                 = {104, 106};
   }
   feature polygon01 GC.Polygon
   {
      Vertices                 = {point02,point01,point08,point07};
   }
   feature polygon02 GC.Polygon
   {
      Vertices                 = {point08,point11,point09,point07,
point08};
   }
   feature polygon03 GC.Polygon
   {
      Vertices                 = {point11,point03,point04,point09};
   }
   feature polygon04 GC.Polygon
   {
      Vertices                 = {point03,point12,point10,point04};
   }
   feature polygon05 GC.Polygon
   {
      Vertices                 = {point12,point05,point06,point10};
   }
}

transaction modelBased "organised symbols"
{
   feature bsplineCurve01 GC.BSplineCurve
   {
      SymbolXY                 = {98, 104};
   }
   feature bsplineCurve02 GC.BSplineCurve
   {
      SymbolXY                 = {100, 104};
   }
   feature bsplineSurface01 GC.BSplineSurface
   {
      SymbolXY                 = {99, 105};
   }
   feature point09 GC.Point
   {
      SymbolXY                 = {103, 104};
   }
   feature point10 GC.Point
   {
      SymbolXY                 = {103, 106};
   }
   feature point11 GC.Point
   {
      SymbolXY                 = {103, 105};
   }
   feature point12 GC.Point
   {
      SymbolXY                 = {103, 103};
   }
   feature polygon01 GC.Polygon
   {
      SymbolXY                 = {109, 107};
   }
   feature polygon02 GC.Polygon
   {
      SymbolXY                 = {109, 105};
   }
   feature polygon03 GC.Polygon
   {
      SymbolXY                 = {109, 106};
   }
   feature polygon04 GC.Polygon
   {
      SymbolXY                 = {109, 104};
   }
   feature polygon05 GC.Polygon
   {
      SymbolXY                 = {109, 103};
   }
}

transaction modelBased "4 point for feature"
{
   feature point13 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (3.30288428389624);
      YTranslation             = <free> (-16.0117010124821);
      ZTranslation             = <free> (0.0);
      SymbolXY                 = {112, 99};
      HandlesVisible           = true;
   }
   feature point14 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (10.0832601592211);
      YTranslation             = <free> (-15.8719158052671);
      ZTranslation             = <free> (0.0);
      SymbolXY                 = {112, 100};
      HandlesVisible           = true;
   }
   feature point15 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (10.3628632881005);
      YTranslation             = <free> (-20.7643980577922);
      ZTranslation             = <free> (0.0);
      SymbolXY                 = {112, 101};
      HandlesVisible           = true;
   }
   feature point16 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (3.79218975943515);
      YTranslation             = <free> (-20.7643980577922);
      ZTranslation             = <free> (0.0);
      SymbolXY                 = {112, 102};
      HandlesVisible           = true;
   }
}

transaction modelBased "polygon feature"
{
   feature point13 GC.Point
   {
      SymbolXY                 = {113, 101};
   }
   feature point14 GC.Point
   {
      SymbolXY                 = {114, 101};
   }
   feature point16 GC.Point
   {
      SymbolXY                 = {111, 101};
   }
   feature polygon06 GC.Polygon
   {
      Vertices                 = {point16,point13,point14,point15};
      SymbolXY                 = {113, 103};
   }
}

transaction modelBased "direction point"
{
   feature direction01 GC.Direction
   {
      Origin                   = polygon06.Vertices[0];
      DirectionPoint           = point17;
      SymbolXY                 = {112, 111};
   }
   feature point13 GC.Point
   {
      Visible                  = false;
   }
   feature point14 GC.Point
   {
      Visible                  = false;
   }
   feature point15 GC.Point
   {
      Visible                  = false;
   }
   feature point16 GC.Point
   {
      Visible                  = false;
   }
   feature point17 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (11.7220451645976);
      YTranslation             = <free> (-25.4368480397014);
      ZTranslation             = <free> (0.0);
      SymbolXY                 = {110, 111};
      HandlesVisible           = true;
   }
}

transaction modelBased "line from direction"
{
   feature line01 GC.Line
   {
      StartPoint               = polygon06.Vertices[0];
      Direction                = direction01;
      Length                   = 1;
   }
   feature point17 GC.Point
   {
      XTranslation             = <free> (5.89180214389051);
      YTranslation             = <free> (-23.4384372995166);
   }
}

transaction modelBased "1 spline on polygon"
{
   feature bsplineCurve03 GC.BSplineCurve
   {
      Points                   = {polygon06.Vertices[0],polygon06.Vertices[1]};
      SymbolXY                 = {117, 111};
   }
   feature line01 GC.Line
   {
      SymbolXY                 = {114, 111};
   }
}

transaction modelBased "1 spline on polygon"
{
   feature bsplineCurve03 GC.BSplineCurve
   {
      SymbolXY                 = {117, 105};
   }
   feature bsplineCurve04 GC.BSplineCurve
   {
      Points                   = {polygon06.Vertices[2],polygon06.Vertices[3]};
      SymbolXY                 = {116, 105};
   }
}

transaction modelBased "surface from splines on polygon"
{
   feature bsplineCurve04 GC.BSplineCurve
   {
      Points                   = {polygon06.Vertices[3],polygon06.Vertices[2]};
   }
   feature bsplineSurface02 GC.BSplineSurface
   {
      Curves                   = {bsplineCurve04,bsplineCurve03};
   }
}

transaction modelBased "coordinatesystem01"
{
   feature bsplineSurface02 GC.BSplineSurface
   {
      SymbolXY                 = {117, 106};
   }
   feature coordinateSystem01 GC.CoordinateSystem
   {
      Surface                  = bsplineSurface02;
      U                        = <free> (0.901490690594512);
      V                        = <free> (0.505413985467503);
      SymbolXY                 = {117, 107};
      HandlesVisible           = true;
   }
}

transaction modelBased "alteration point on line endpoint"
{
   feature point18 GC.Point
   {
      Origin                   = line01.EndPoint;
      Direction                = coordinateSystem01.ZDirection;
      DistanceFromOrigin       = 2;
      SymbolXY                 = {117, 111};
   }
}

transaction modelBased "3 points from polygon"
{
   feature point17 GC.Point
   {
      XTranslation             = <free> (1.7668349158719);
      YTranslation             = <free> (-24.1178847145571);
   }
   feature point19 GC.Point
   {
      Origin                   = polygon06.Vertices[1];
      Direction                = coordinateSystem01.ZDirection;
      DistanceFromOrigin       = 1;
   }
   feature point20 GC.Point
   {
      Origin                   = polygon06.Vertices[2];
      Direction                = coordinateSystem01.ZDirection;
      DistanceFromOrigin       = 1;
   }
   feature point21 GC.Point
   {
      Origin                   = polygon06.Vertices[3];
      Direction                = coordinateSystem01.ZDirection;
      DistanceFromOrigin       = 1;
   }
}

transaction modelBased "4 splines for surface"
{
   feature bsplineCurve05 GC.BSplineCurve
   {
      Points                   = {point19,point20};
      SymbolXY                 = {119, 116};
   }
   feature bsplineCurve06 GC.BSplineCurve
   {
      Points                   = {point18,point21};
      SymbolXY                 = {117, 116};
   }
   feature bsplineCurve07 GC.BSplineCurve
   {
      Points                   = {polygon06.Vertices[1],polygon06.Vertices[2]};
      SymbolXY                 = {114, 116};
   }
   feature bsplineCurve08 GC.BSplineCurve
   {
      Points                   = {polygon06.Vertices[0],polygon06.Vertices[3]};
      SymbolXY                 = {115, 116};
   }
   feature line01 GC.Line
   {
      SymbolXY                 = {113, 111};
   }
   feature point18 GC.Point
   {
      SymbolXY                 = {116, 114};
   }
   feature point19 GC.Point
   {
      SymbolXY                 = {118, 114};
   }
   feature point20 GC.Point
   {
      SymbolXY                 = {119, 114};
   }
   feature point21 GC.Point
   {
      SymbolXY                 = {117, 114};
   }
}

transaction modelBased "3 surfaces"
{
   feature bsplineCurve05 GC.BSplineCurve
   {
      SymbolXY                 = {118, 116};
   }
   feature bsplineCurve07 GC.BSplineCurve
   {
```



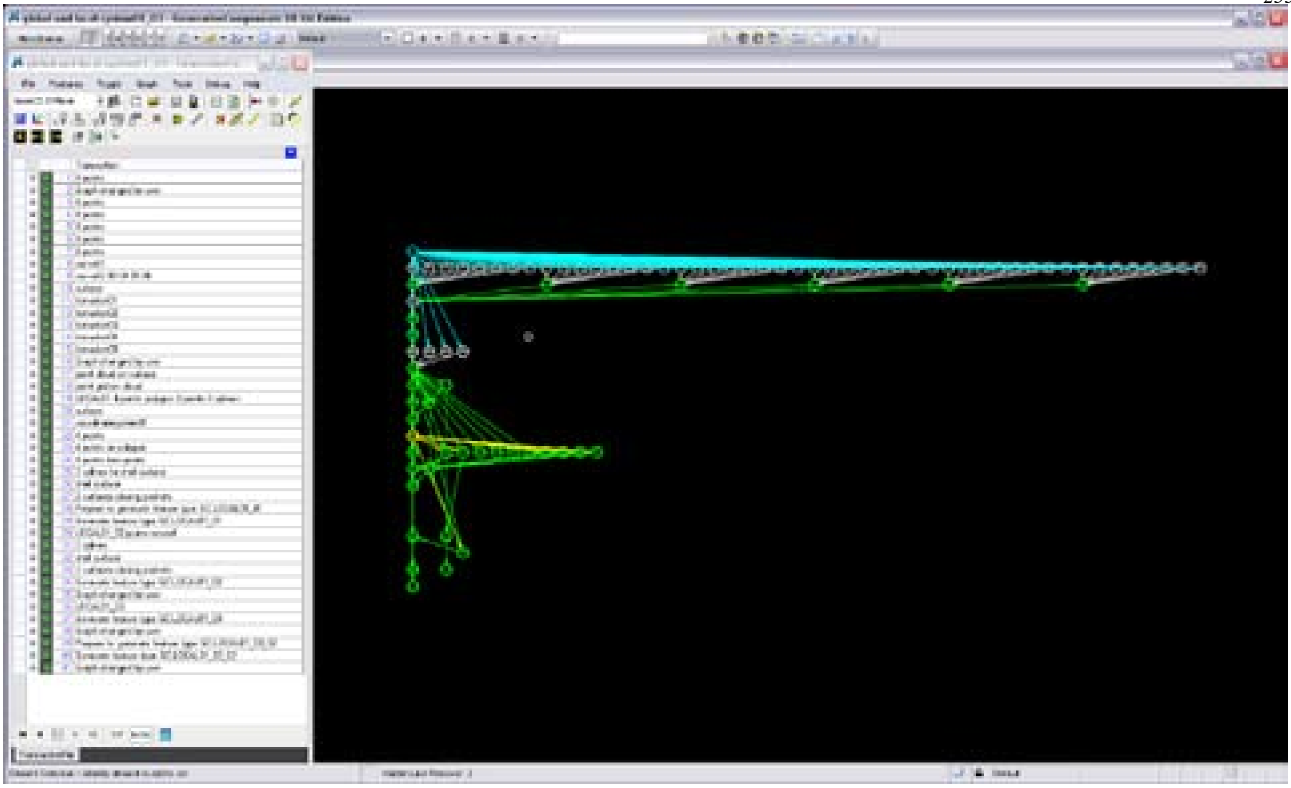


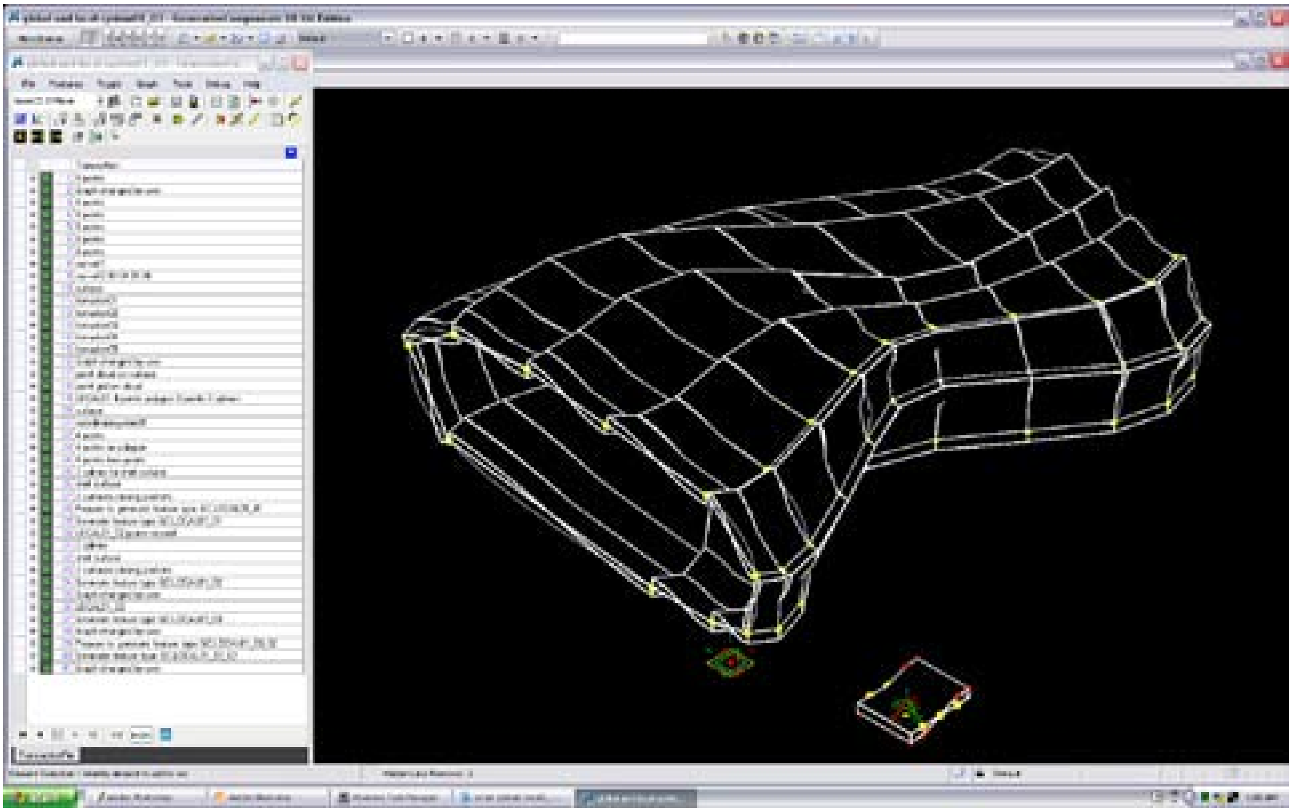
```
transaction modelBased “8 points”
{
    feature point01 GC.Point
    {
        CoordinateSystem        = baseCS;
        XTranslation            = 1;
        YTranslation            = 6;
        ZTranslation            = 5;
        HandlesVisible          = true;
    }
    feature point02 GC.Point
    {
        CoordinateSystem        = baseCS;
        XTranslation            = 1;
        YTranslation            = 4;
        ZTranslation            = 5;
        HandlesVisible          = true;
    }
    feature point03 GC.Point
    {
        CoordinateSystem        = baseCS;
        XTranslation            = <free> (1);
        YTranslation            = <free> (2);
        ZTranslation            = <free> (5);
        HandlesVisible          = true;
    }
    feature point04 GC.Point
    {
        CoordinateSystem        = baseCS;
        XTranslation            = 1;
        YTranslation            = 0;
        ZTranslation            = 5;
        HandlesVisible          = true;
    }
    feature point05 GC.Point
    {
        CoordinateSystem        = baseCS;
        XTranslation            = <free> (1);
        YTranslation            = <free> (6);
        ZTranslation            = <free> (0.0);
        HandlesVisible          = true;
    }
    feature point06 GC.Point
    {
        CoordinateSystem        = baseCS;
        XTranslation            = <free> (1);
        YTranslation            = <free> (4);
        ZTranslation            = <free> (0.0);
        HandlesVisible          = true;
    }
    feature point07 GC.Point
    {
        CoordinateSystem        = baseCS;
        XTranslation            = <free> (1);
        YTranslation            = <free> (2);
        ZTranslation            = <free> (0.0);
        HandlesVisible          = true;
    }
    feature point08 GC.Point
    {
        CoordinateSystem        = baseCS;
        XTranslation            = <free> (1);
        YTranslation            = <free> (0);
        ZTranslation            = <free> (0.0);
        HandlesVisible          = true;
    }
}

transaction modelBased “Graph changed by user”
{
    feature point01 GC.Point
    {
        XTranslation            = <free> (1);
        YTranslation            = <free> (6);
        ZTranslation            = <free> (5);
    }
    feature point02 GC.Point
    {
        XTranslation            = <free> (1);
        YTranslation            = <free> (4);
        ZTranslation            = <free> (5);
    }
    feature point04 GC.Point
    {
        XTranslation            = <free> (1);
        YTranslation            = <free> (0);
        ZTranslation            = <free> (5);
    }
}

transaction modelBased “8 points”
{
    feature point09 GC.Point
    {
        CoordinateSystem        = baseCS;
        XTranslation            = <free> (3);
        YTranslation            = <free> (6);
        ZTranslation            = <free> (5);
    }
    feature point10 GC.Point
    {
        CoordinateSystem        = baseCS;
        XTranslation            = <free> (3);
        YTranslation            = <free> (4);
        ZTranslation            = <free> (5);
    }
    feature point11 GC.Point
    {
        CoordinateSystem        = baseCS;
        XTranslation            = <free> (3);
        YTranslation            = <free> (2);
        ZTranslation            = <free> (5);
    }
    feature point12 GC.Point
    {
        CoordinateSystem        = baseCS;
        XTranslation            = <free> (3);
        YTranslation            = <free> (0);
        ZTranslation            = <free> (5);
    }
    feature point13 GC.Point
    {
        CoordinateSystem        = baseCS;
        XTranslation            = <free> (3);
        YTranslation            = <free> (6);
        ZTranslation            = <free> (0.0);
    }
    feature point14 GC.Point
    {
        CoordinateSystem        = baseCS;
        XTranslation            = <free> (3);
        YTranslation            = <free> (4);
        ZTranslation            = <free> (0.0);
    }
    feature point15 GC.Point
    {
        CoordinateSystem        = baseCS;
        XTranslation            = <free> (3);
        YTranslation            = <free> (2);
        ZTranslation            = <free> (0.0);
    }
    feature point16 GC.Point
    {
        CoordinateSystem        = baseCS;
        XTranslation            = <free> (3);
        YTranslation            = <free> (0);
        ZTranslation            = <free> (0.0);
    }
}

transaction modelBased “8 points”
{
    feature point17 GC.Point
    {
        CoordinateSystem        = baseCS;
        XTranslation            = <free> (7);
        YTranslation            = <free> (6);
        ZTranslation            = <free> (5);
    }
    feature point18 GC.Point
    {
        CoordinateSystem        = baseCS;
        XTranslation            = <free> (7);
        YTranslation            = <free> (4);
        ZTranslation            = <free> (5);
    }
    feature point19 GC.Point
    {
        CoordinateSystem        = baseCS;
        XTranslation            = <free> (7);
        YTranslation            = <free> (2);
        ZTranslation            = <free> (5);
    }
    feature point20 GC.Point
    {
        CoordinateSystem        = baseCS;
        XTranslation            = <free> (7);
        YTranslation            = <free> (0);
        ZTranslation            = <free> (5);
    }
    feature point21 GC.Point
    {
        CoordinateSystem        = baseCS;
        XTranslation            = <free> (7);
        YTranslation            = <free> (6);
        ZTranslation            = <free> (0.0);
    }
    feature point22 GC.Point
    {
        CoordinateSystem        = baseCS;
        XTranslation            = <free> (7);
        YTranslation            = <free> (4);
        ZTranslation            = <free> (0.0);
    }
    feature point23 GC.Point
    {
        CoordinateSystem        = baseCS;
        XTranslation            = <free> (7);
        YTranslation            = <free> (2);
        ZTranslation            = <free> (0.0);
    }
    feature point24 GC.Point
    {
        CoordinateSystem        = baseCS;
        XTranslation            = <free> (7);
        YTranslation            = <free> (0);
        ZTranslation            = <free> (0.0);
    }
}

transaction modelBased “8 points”
{
    feature point25 GC.Point
    {
        CoordinateSystem        = baseCS;
        XTranslation            = <free> (11);
        YTranslation            = <free> (6);
        ZTranslation            = <free> (5);
    }
    feature point26 GC.Point
    {
        CoordinateSystem        = baseCS;
        XTranslation            = <free> (11);
        YTranslation            = <free> (4);
        ZTranslation            = <free> (5);
    }
    feature point27 GC.Point
    {
        CoordinateSystem        = baseCS;
        XTranslation            = <free> (11);
        YTranslation            = <free> (2);
        ZTranslation            = <free> (5);
    }
    feature point28 GC.Point
    {
        CoordinateSystem        = baseCS;
        XTranslation            = <free> (11);
        YTranslation            = <free> (0);
        ZTranslation            = <free> (5);
    }
    feature point29 GC.Point
    {
        CoordinateSystem        = baseCS;
        XTranslation            = <free> (11);
        YTranslation            = <free> (6);
        ZTranslation            = <free> (0.0);
    }
    feature point30 GC.Point
    {
        CoordinateSystem        = baseCS;
        XTranslation            = <free> (11);
        YTranslation            = <free> (4);
        ZTranslation            = <free> (0.0);
    }
    feature point31 GC.Point
    {
        CoordinateSystem        = baseCS;
        XTranslation            = <free> (11);
        YTranslation            = <free> (2);
        ZTranslation            = <free> (0.0);
    }
    feature point32 GC.Point
    {
        CoordinateSystem        = baseCS;
        XTranslation            = <free> (11);
        YTranslation            = <free> (0);
        ZTranslation            = <free> (0.0);
    }
}

transaction modelBased “8 points”
{
    feature point33 GC.Point
    {
        CoordinateSystem        = baseCS;
        XTranslation            = <free> (15);
        YTranslation            = <free> (6);
        ZTranslation            = <free> (5);
    }
    feature point34 GC.Point
    {
        CoordinateSystem        = baseCS;
        XTranslation            = <free> (15);
        YTranslation            = <free> (4);
        ZTranslation            = <free> (5);
    }
    feature point35 GC.Point
    {
        CoordinateSystem        = baseCS;
        XTranslation            = <free> (15);
        YTranslation            = <free> (2);
        ZTranslation            = <free> (5);
    }
    feature point36 GC.Point
    {
        CoordinateSystem        = baseCS;
        XTranslation            = <free> (15);
        YTranslation            = <free> (0);
        ZTranslation            = <free> (5);
    }
    feature point37 GC.Point
    {
        CoordinateSystem        = baseCS;
        XTranslation            = <free> (15);
        YTranslation            = <free> (6);
        ZTranslation            = <free> (0.0);
    }
    feature point38 GC.Point
    {
        CoordinateSystem        = baseCS;
        XTranslation            = <free> (15);
        YTranslation            = <free> (4);
        ZTranslation            = <free> (0.0);
    }
    feature point39 GC.Point
    {
        CoordinateSystem        = baseCS;
        XTranslation            = <free> (15);
        YTranslation            = <free> (2);
        ZTranslation            = <free> (0.0);
    }
    feature point40 GC.Point
    {
        CoordinateSystem        = baseCS;
        XTranslation            = <free> (15);
        YTranslation            = <free> (0);
        ZTranslation            = <free> (0.0);
    }
}

transaction modelBased “8 points”
{
    feature point41 GC.Point
    {
        CoordinateSystem        = baseCS;
        XTranslation            = <free> (18);
        YTranslation            = <free> (6);
        ZTranslation            = <free> (5);
    }
    feature point42 GC.Point
    {
        CoordinateSystem        = baseCS;
        XTranslation            = <free> (18);
        YTranslation            = <free> (4);
        ZTranslation            = <free> (5);
    }
    feature point43 GC.Point
    {
        CoordinateSystem        = baseCS;
        XTranslation            = <free> (18);
        YTranslation            = <free> (2);
        ZTranslation            = <free> (5);
    }
    feature point44 GC.Point
    {
        CoordinateSystem        = baseCS;
        XTranslation            = <free> (18);
        YTranslation            = <free> (0);
        ZTranslation            = <free> (5);
    }
    feature point45 GC.Point
    {
        CoordinateSystem        = baseCS;
        XTranslation            = <free> (18);
        YTranslation            = <free> (6);
        ZTranslation            = <free> (0.0);
    }
    feature point46 GC.Point
    {
        CoordinateSystem        = baseCS;
        XTranslation            = <free> (18);
        YTranslation            = <free> (4);
        ZTranslation            = <free> (0.0);
    }
    feature point47 GC.Point
    {
        CoordinateSystem        = baseCS;
        XTranslation            = <free> (18);
        YTranslation            = <free> (2);
        ZTranslation            = <free> (0.0);
    }
    feature point48 GC.Point
    {
        CoordinateSystem        = baseCS;
        XTranslation            = <free> (18);
        YTranslation            = <free> (0);
        ZTranslation            = <free> (0.0);
    }
}

transaction modelBased “curve01”
{
    feature bsplineCurve01 GC.BSplineCurve
    {
        Poles                   = {point06,point05,point01,point02,point03,point04
,point08,point07,point06};
        Order                   = 4;
    }
}

transaction modelBased “curve02 03 04 05 06”
{
    feature bsplineCurve02 GC.BSplineCurve
    {
        Poles                   = {point14,point13,point09,point10,point11,point12
,point16,point15,point14};
        Order                   = 4;
    }
    feature bsplineCurve03 GC.BSplineCurve
    {
        Poles                   = {point22,point21,point17,point18,point19,point20
,point24,point23,point22};
        Order                   = 4;
    }
    feature bsplineCurve04 GC.BSplineCurve
    {
        Poles                   = {point30,point29,point25,point26,point27,point28
,point32,point31,point30};
        Order                   = 4;
    }
    feature bsplineCurve05 GC.BSplineCurve
    {
        Poles                   = {point38,point37,point33,point34,point35,point36
,point40,point39,point38};
        Order                   = 4;
    }
    feature bsplineCurve06 GC.BSplineCurve
    {
        Poles                   = {point46,point45,point41,point42,point43,point44
,point48,point47,point46};
        Order                   = 4;
    }
}

transaction modelBased “surface”
{
    feature bsplineSurface01 GC.BSplineSurface
    {
        Curves                  = {bsplineCurve01,bsplineCurve02,bsplineCurve0
3,bsplineCurve04,bsplineCurve05,bsplineCurve06};
    }
}

transaction modelBased “formation01”
{
    feature point01 GC.Point
    {
        YTranslation            = 14;
    }
    feature point05 GC.Point
    {
        YTranslation            = 14;
    }
    feature point09 GC.Point
    {
        YTranslation            = 15;
    }
    feature point13 GC.Point
    {
        YTranslation            = 15;
    }
    feature point17 GC.Point
    {
        YTranslation            = 14;
    }
    feature point18 GC.Point
    {
        YTranslation            = 7;
    }
    feature point19 GC.Point
    {
        YTranslation            = 5;
    }
    feature point20 GC.Point
    {
        YTranslation            = 3;
    }
    feature point21 GC.Point
    {
        YTranslation            = 12;
    }
    feature point22 GC.Point
    {
        YTranslation            = 7;
    }
    feature point23 GC.Point
    {
        YTranslation            = 6;
    }
    feature point24 GC.Point
    {
        YTranslation            = 5;
    }
    feature point25 GC.Point
    {
        YTranslation            = 9;
    }
    feature point26 GC.Point
    {
        YTranslation            = 5;
    }
    feature point27 GC.Point
    {
        YTranslation            = 4;
    }
    feature point28 GC.Point
    {
        YTranslation            = 3;
    }
    feature point33 GC.Point
    {
        YTranslation            = 10;
    }
    feature point41 GC.Point
    {
        YTranslation            = 10;
    }
}

transaction modelBased “formation02”
```



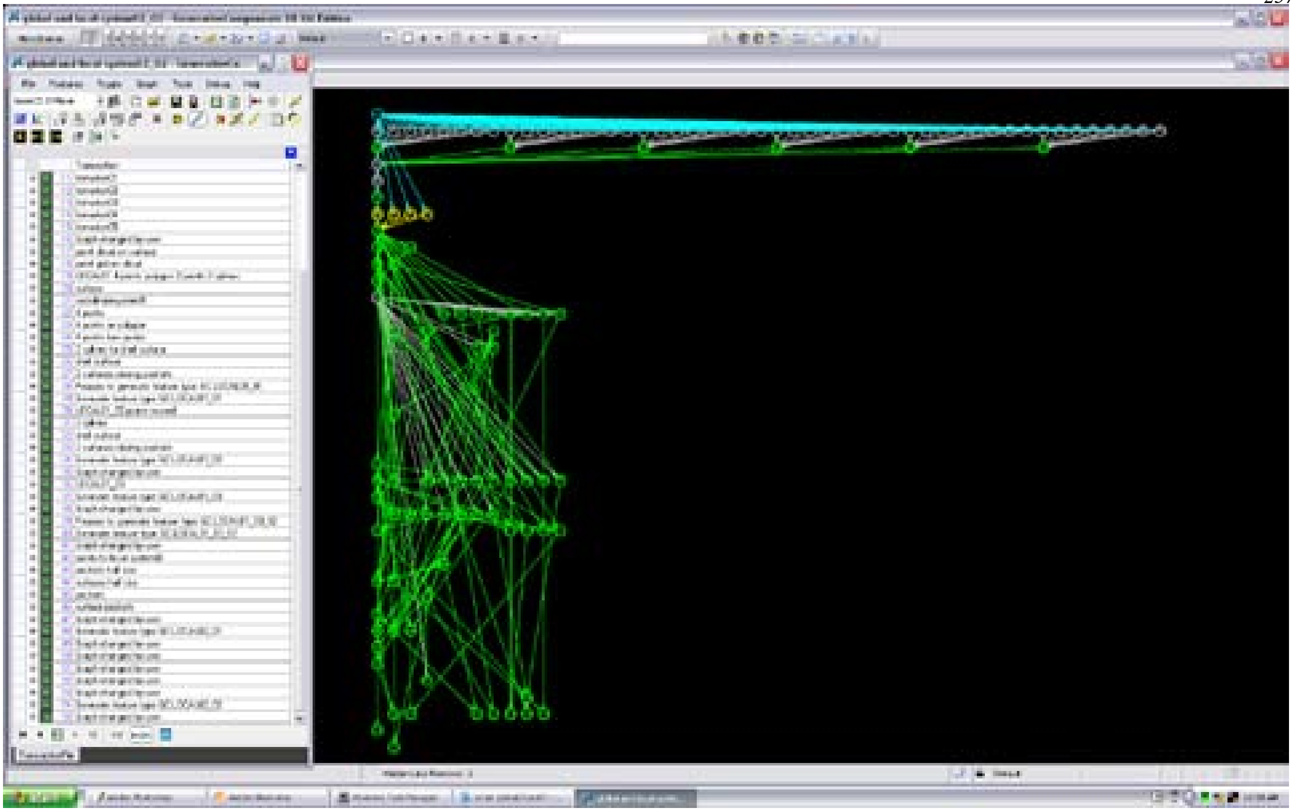


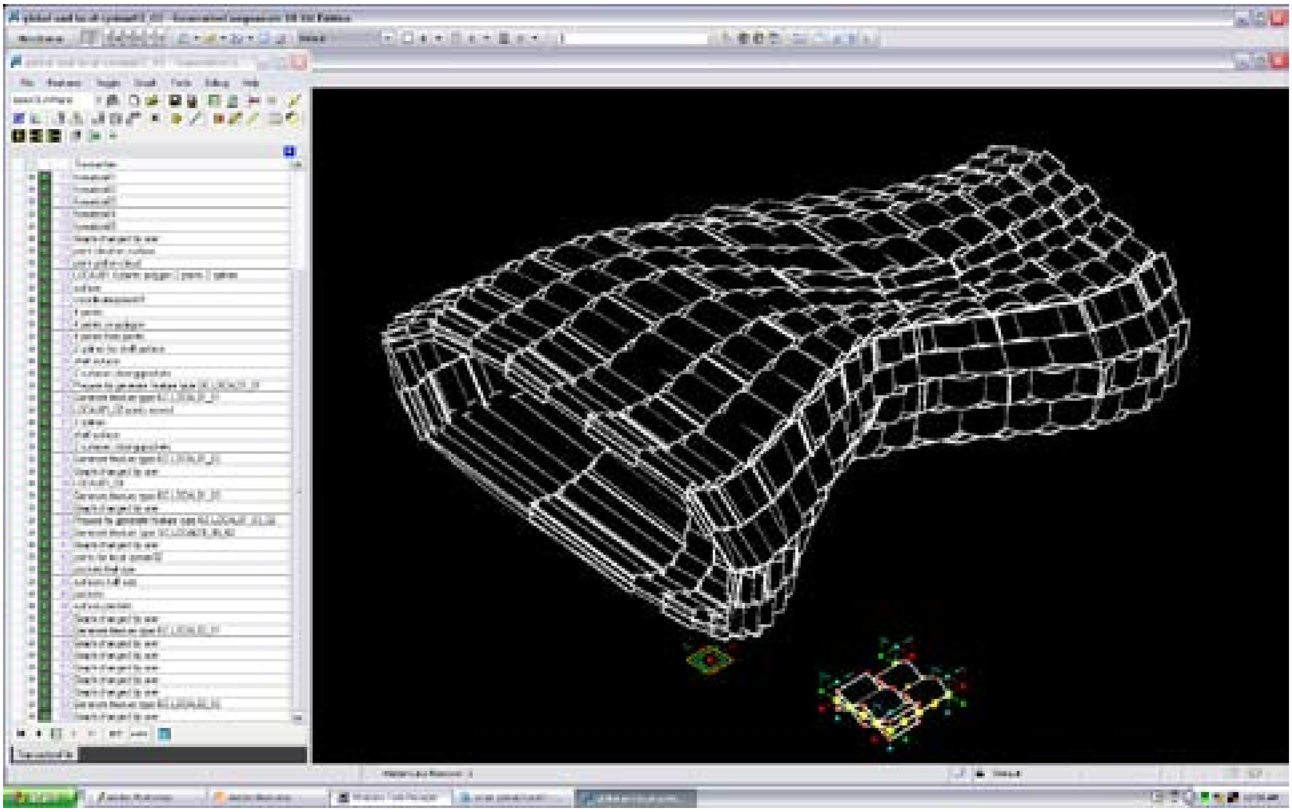
```
transaction modelBased “8 points”
{
   feature point01 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = 1;
      YTranslation             = 6;
      ZTranslation             = 5;
      HandlesVisible           = true;
   }
   feature point02 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = 1;
      YTranslation             = 4;
      ZTranslation             = 5;
      HandlesVisible           = true;
   }
   feature point03 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (1);
      YTranslation             = <free> (2);
      ZTranslation             = <free> (5);
      HandlesVisible           = true;
   }
   feature point04 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = 1;
      YTranslation             = 0;
      ZTranslation             = 5;
      HandlesVisible           = true;
   }
   feature point05 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (1);
      YTranslation             = <free> (6);
      ZTranslation             = <free> (0.0);
      HandlesVisible           = true;
   }
   feature point06 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (1);
      YTranslation             = <free> (4);
      ZTranslation             = <free> (0.0);
      HandlesVisible           = true;
   }
   feature point07 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (1);
      YTranslation             = <free> (2);
      ZTranslation             = <free> (0.0);
      HandlesVisible           = true;
   }
   feature point08 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (1);
      YTranslation             = <free> (0);
      ZTranslation             = <free> (0.0);
      HandlesVisible           = true;
   }
}

transaction modelBased “Graph changed by user”
{
   feature point01 GC.Point
   {
      XTranslation             = <free> (1);
      YTranslation             = <free> (6);
      ZTranslation             = <free> (5);
   }
   feature point02 GC.Point
   {
      XTranslation             = <free> (1);
      YTranslation             = <free> (4);
      ZTranslation             = <free> (5);
   }
   feature point04 GC.Point
   {
      XTranslation             = <free> (1);
      YTranslation             = <free> (0);
      ZTranslation             = <free> (5);
   }
}

transaction modelBased “8 points”
{
   feature point09 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (3);
      YTranslation             = <free> (6);
      ZTranslation             = <free> (5);
   }
   feature point10 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (3);
      YTranslation             = <free> (4);
      ZTranslation             = <free> (5);
   }
   feature point11 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (3);
      YTranslation             = <free> (2);
      ZTranslation             = <free> (5);
   }
   feature point12 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (3);
      YTranslation             = <free> (0);
      ZTranslation             = <free> (5);
   }
   feature point13 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (3);
      YTranslation             = <free> (6);
      ZTranslation             = <free> (0.0);
   }
   feature point14 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (3);
      YTranslation             = <free> (4);
      ZTranslation             = <free> (0.0);
   }
   feature point15 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (3);
      YTranslation             = <free> (2);
      ZTranslation             = <free> (0.0);
   }
   feature point16 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (3);
      YTranslation             = <free> (0);
      ZTranslation             = <free> (0.0);
   }
}

transaction modelBased “8 points”
{
   feature point17 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (7);
      YTranslation             = <free> (6);
      ZTranslation             = <free> (5);
   }
   feature point18 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (7);
      YTranslation             = <free> (4);
      ZTranslation             = <free> (5);
   }
   feature point19 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (7);
      YTranslation             = <free> (2);
      ZTranslation             = <free> (5);
   }
   feature point20 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (7);
      YTranslation             = <free> (0);
      ZTranslation             = <free> (5);
   }
   feature point21 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (7);
      YTranslation             = <free> (6);
      ZTranslation             = <free> (0.0);
   }
   feature point22 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (7);
      YTranslation             = <free> (4);
      ZTranslation             = <free> (0.0);
   }
   feature point23 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (7);
      YTranslation             = <free> (2);
      ZTranslation             = <free> (0.0);
   }
   feature point24 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (7);
      YTranslation             = <free> (0);
      ZTranslation             = <free> (0.0);
   }
}

transaction modelBased “8 points”
{
   feature point25 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (11);
      YTranslation             = <free> (6);
      ZTranslation             = <free> (5);
   }
   feature point26 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (11);
      YTranslation             = <free> (4);
      ZTranslation             = <free> (5);
   }
   feature point27 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (11);
      YTranslation             = <free> (2);
      ZTranslation             = <free> (5);
   }
   feature point28 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (11);
      YTranslation             = <free> (0);
      ZTranslation             = <free> (5);
   }
   feature point29 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (11);
      YTranslation             = <free> (6);
      ZTranslation             = <free> (0.0);
   }
   feature point30 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (11);
      YTranslation             = <free> (4);
      ZTranslation             = <free> (0.0);
   }
   feature point31 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (11);
      YTranslation             = <free> (2);
      ZTranslation             = <free> (0.0);
   }
   feature point32 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (11);
      YTranslation             = <free> (0);
      ZTranslation             = <free> (0.0);
   }
}

transaction modelBased “8 points”
{
   feature point33 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (15);
      YTranslation             = <free> (6);
      ZTranslation             = <free> (5);
   }
   feature point34 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (15);
      YTranslation             = <free> (4);
      ZTranslation             = <free> (5);
   }
   feature point35 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (15);
      YTranslation             = <free> (2);
      ZTranslation             = <free> (5);
   }
   feature point36 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (15);
      YTranslation             = <free> (0);
      ZTranslation             = <free> (5);
   }
   feature point37 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (15);
      YTranslation             = <free> (6);
      ZTranslation             = <free> (0.0);
   }
   feature point38 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (15);
      YTranslation             = <free> (4);
      ZTranslation             = <free> (0.0);
   }
   feature point39 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (15);
      YTranslation             = <free> (2);
      ZTranslation             = <free> (0.0);
   }
   feature point40 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (15);
      YTranslation             = <free> (0);
      ZTranslation             = <free> (0.0);
   }
}

transaction modelBased “8 points”
{
   feature point41 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (18);
      YTranslation             = <free> (6);
      ZTranslation             = <free> (5);
   }
   feature point42 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (18);
      YTranslation             = <free> (4);
      ZTranslation             = <free> (5);
   }
   feature point43 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (18);
      YTranslation             = <free> (2);
      ZTranslation             = <free> (5);
   }
   feature point44 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (18);
      YTranslation             = <free> (0);
      ZTranslation             = <free> (5);
   }
   feature point45 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (18);
      YTranslation             = <free> (6);
      ZTranslation             = <free> (0.0);
   }
   feature point46 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (18);
      YTranslation             = <free> (4);
      ZTranslation             = <free> (0.0);
   }
   feature point47 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (18);
      YTranslation             = <free> (2);
      ZTranslation             = <free> (0.0);
   }
   feature point48 GC.Point
   {
      CoordinateSystem         = baseCS;
      XTranslation             = <free> (18);
      YTranslation             = <free> (0);
      ZTranslation             = <free> (0.0);
   }
}

transaction modelBased “curve01”
{
   feature bsplineCurve01 GC.BSplineCurve
   {
      Poles                    = {point06,point05,point01,point02,point03,point04,poin
t08,point07,point06};
      Order                    = 4;
   }
}

transaction modelBased “curve02 03 04 05 06”
{
   feature bsplineCurve02 GC.BSplineCurve
   {
      Poles                    = {point14,point13,point09,point10,point11,point12,poin
t16,point15,point14};
      Order                    = 4;
   }
   feature bsplineCurve03 GC.BSplineCurve
   {
      Poles                    = {point22,point21,point17,point18,point19,point20,poin
t24,point23,point22};
      Order                    = 4;
   }
   feature bsplineCurve04 GC.BSplineCurve
   {
      Poles                    = {point30,point29,point25,point26,point27,point28,poin
t32,point31,point30};
      Order                    = 4;
   }
   feature bsplineCurve05 GC.BSplineCurve
   {
      Poles                    = {point38,point37,point33,point34,point35,point36,poin
t40,point39,point38};
      Order                    = 4;
   }
   feature bsplineCurve06 GC.BSplineCurve
   {
      Poles                    = {point46,point45,point41,point42,point43,point44,poin
t48,point47,point46};
      Order                    = 4;
   }
}

transaction modelBased “surface”
{
   feature bsplineSurface01 GC.BSplineSurface
   {
      Curves                   = {bsplineCurve01,bsplineCurve02,bsplineCurve03,bspline
Curve04,bsplineCurve05,bsplineCurve06};
   }
}

transaction modelBased “formation01”
{
   feature point01 GC.Point
   {
      YTranslation             = 14;
   }
   feature point05 GC.Point
   {
      YTranslation             = 14;
   }
   feature point09 GC.Point
   {
      YTranslation             = 15;
   }
   feature point13 GC.Point
   {
      YTranslation             = 15;
   }
   feature point17 GC.Point
   {
      YTranslation             = 14;
   }
   feature point18 GC.Point
   {
      YTranslation             = 7;
   }
   feature point19 GC.Point
   {
      YTranslation             = 5;
   }
   feature point20 GC.Point
   {
      YTranslation             = 3;
   }
   feature point21 GC.Point
   {
      YTranslation             = 12;
   }
   feature point22 GC.Point
   {
      YTranslation             = 7;
   }
   feature point23 GC.Point
   {
      YTranslation             = 6;
   }
   feature point24 GC.Point
   {
      YTranslation             = 5;
   }
   feature point25 GC.Point
   {
      YTranslation             = 9;
   }
   feature point26 GC.Point
   {
      YTranslation             = 5;
   }
   feature point27 GC.Point
   {
      YTranslation             = 4;
   }
   feature point28 GC.Point
   {
      YTranslation             = 3;
   }
   feature point33 GC.Point
   {
      YTranslation             = 10;
   }
   feature point41 GC.Point
   {
      YTranslation             = 10;
   }
}

transaction modelBased “formation02”
{
```



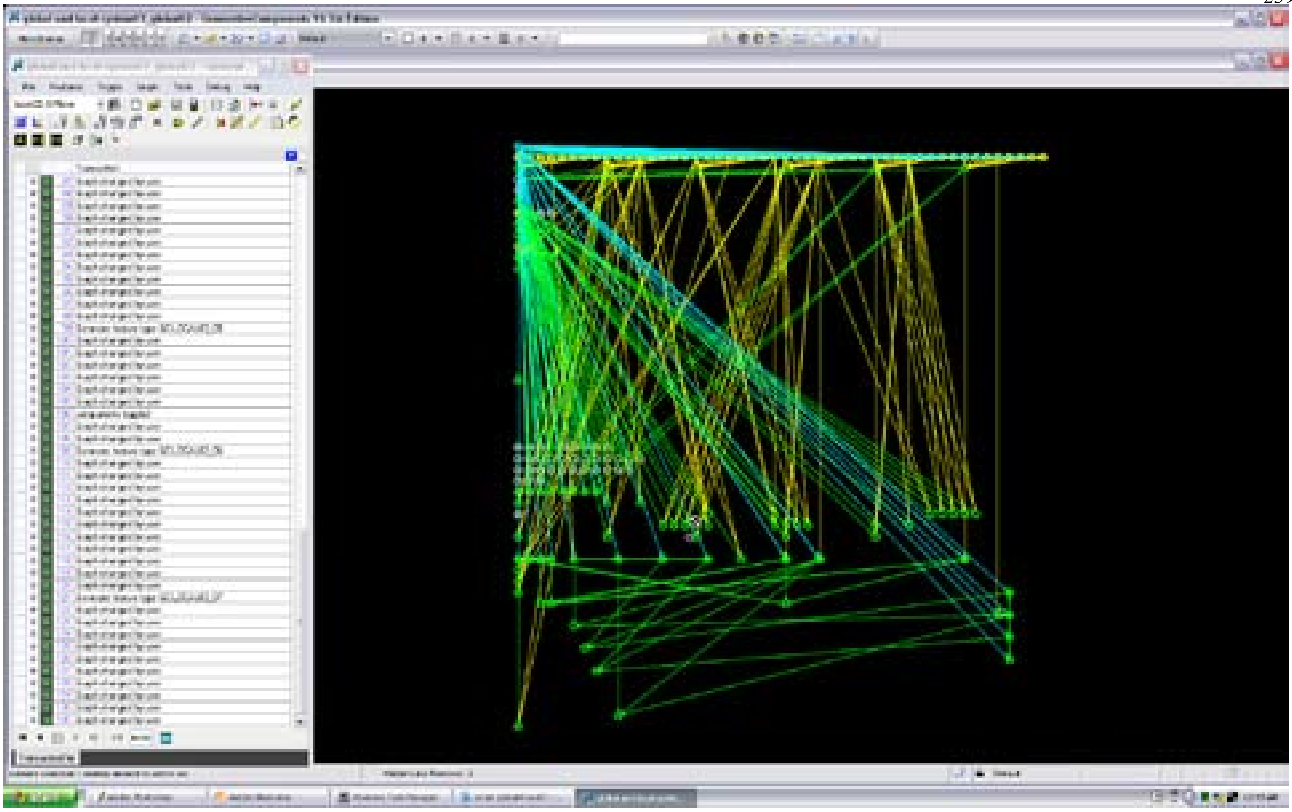


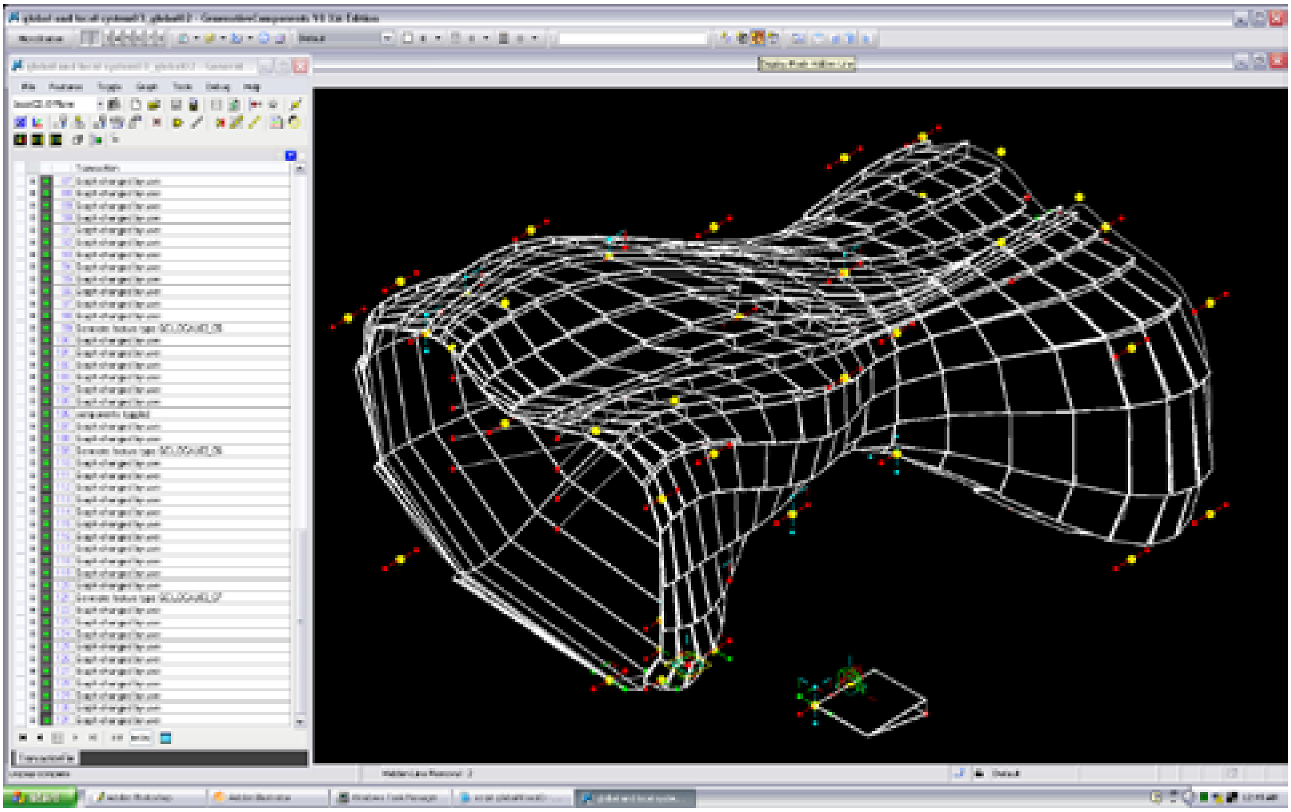
```
    feature point09 GC.Point
    {
        YTranslation            = 14;
    }
    feature point13 GC.Point
    {
        YTranslation            = 14;
    }
    feature point17 GC.Point
    {
        YTranslation            = 13;
    }
    feature point20 GC.Point
    {
        YTranslation            = 1;
    }
    feature point24 GC.Point
    {
        YTranslation            = 3;
    }
    feature point25 GC.Point
    {
        YTranslation            = 12;
    }
    feature point29 GC.Point
    {
        YTranslation            = 8;
    }
}

transaction modelBased "formation03"
{
    feature point02 GC.Point
    {
        YTranslation            = 8;
    }
    feature point03 GC.Point
    {
        YTranslation            = 6;
    }
    feature point27 GC.Point
    {
        ZTranslation            = 3;
    }
    feature point28 GC.Point
    {
        ZTranslation            = 4;
    }
    feature point32 GC.Point
    {
        YTranslation            = 3;
    }
    feature point35 GC.Point
    {
        YTranslation            = 3;
        ZTranslation            = 3;
    }
    feature point36 GC.Point
    {
        ZTranslation            = 4;
    }
    feature point43 GC.Point
    {
        YTranslation            = 3;
        ZTranslation            = 3;
    }
    feature point44 GC.Point
    {
        ZTranslation            = 4;
    }
}

transaction modelBased "formation04"
{
    feature point37 GC.Point
    {
        YTranslation            = 10;
        ZTranslation            = -2;
    }
    feature point38 GC.Point
    {
        ZTranslation            = -2;
    }
    feature point39 GC.Point
    {
        ZTranslation            = -2;
    }
    feature point45 GC.Point
    {
        YTranslation            = 10;
        ZTranslation            = -2;
    }
    feature point46 GC.Point
    {
        ZTranslation            = -2;
    }
    feature point47 GC.Point
    {
        ZTranslation            = -2;
    }
    feature point48 GC.Point
    {
        ZTranslation            = -2;
    }
}

transaction modelBased "formation05"
{
    feature bsplineCurve01 GC.BSplineCurve
    {
        Order                   = 2;
    }
    feature bsplineCurve02 GC.BSplineCurve
    {
        Order                   = 2;
    }
    feature bsplineCurve03 GC.BSplineCurve
    {
        Order                   = 2;
    }
    feature bsplineCurve04 GC.BSplineCurve
    {
        Order                   = 2;
    }
    feature bsplineCurve05 GC.BSplineCurve
    {
        Order                   = 2;
    }
    feature bsplineCurve06 GC.BSplineCurve
    {
        Order                   = 2;
    }
    feature point01 GC.Point
    {
        ZTranslation            = 4;
    }
    feature point02 GC.Point
    {
        YTranslation            = 10;
    }
    feature point03 GC.Point
    {
        ZTranslation            = 4.5;
    }
    feature point04 GC.Point
    {
        ZTranslation            = 4;
    }
    feature point05 GC.Point
    {
        YTranslation            = 12;
    }
    feature point09 GC.Point
    {
        ZTranslation            = 4.2;
    }
    feature point10 GC.Point
    {
        YTranslation            = 10.5;
    }
    feature point11 GC.Point
    {
        YTranslation            = 5;
        ZTranslation            = 4.5;
    }
    feature point12 GC.Point
    {
        ZTranslation            = 4;
    }
    feature point13 GC.Point
    {
        YTranslation            = 12;
    }
    feature point17 GC.Point
    {
        ZTranslation            = 4.4;
    }
    feature point18 GC.Point
    {
        YTranslation            = 10;
    }
    feature point21 GC.Point
    {
        YTranslation            = 10;
    }
    feature point25 GC.Point
    {
        ZTranslation            = 4.6;
    }
    feature point27 GC.Point
    {
        ZTranslation            = 4;
    }
    feature point33 GC.Point
    {
        YTranslation            = 8;
        ZTranslation            = 4.8;
    }
    feature point35 GC.Point
    {
        ZTranslation            = 4;
    }
    feature point37 GC.Point
    {
        YTranslation            = 9;
        ZTranslation            = 0;
    }
    feature point38 GC.Point
    {
        ZTranslation            = -1;
    }
    feature point39 GC.Point
    {
        ZTranslation            = -1;
    }
    feature point41 GC.Point
    {
        YTranslation            = 7;
    }
    feature point43 GC.Point
    {
        ZTranslation            = 4;
    }
    feature point45 GC.Point
    {
        YTranslation            = 9;
        ZTranslation            = 0;
    }
    feature point46 GC.Point
    {
        ZTranslation            = -1.5;
    }
    feature point47 GC.Point
    {
        ZTranslation            = -1.5;
    }
    feature point48 GC.Point
    {
        ZTranslation            = -1.5;
    }
}

transaction modelBased "Graph changed by user"
{
    feature point30 GC.Point
    {
        YTranslation            = 6;
    }
    feature point31 GC.Point
    {
        YTranslation            = 4;
    }
    feature point38 GC.Point
    {
        ZTranslation            = 0;
    }
    feature point39 GC.Point
    {
        ZTranslation            = 0;
    }
    feature point46 GC.Point
    {
        ZTranslation            = 0;
    }
    feature point47 GC.Point
    {
        ZTranslation            = -0;
    }
    feature point48 GC.Point
    {
        ZTranslation            = 0;
    }
}

transaction modelBased "point cloud on surface"
{
    feature bsplineCurve01 GC.BSplineCurve
    {
        Order                   = 3;
    }
    feature bsplineCurve02 GC.BSplineCurve
    {
        Order                   = 3;
    }
    feature bsplineCurve03 GC.BSplineCurve
    {
        Order                   = 3;
    }
    feature bsplineCurve04 GC.BSplineCurve
    {
        Order                   = 3;
    }
    feature bsplineCurve05 GC.BSplineCurve
    {
        Order                   = 3;
    }
    feature bsplineCurve06 GC.BSplineCurve
    {
        Order                   = 3;
    }
    feature point01 GC.Point
    {
        Visible                 = false;
    }
    feature point02 GC.Point
    {
        Visible                 = false;
    }
    feature point03 GC.Point
    {
        Visible                 = false;
    }
    feature point04 GC.Point
    {
        Visible                 = false;
    }
    feature point05 GC.Point
    {
        Visible                 = false;
    }
    feature point06 GC.Point
    {
        Visible                 = false;
    }
    feature point07 GC.Point
    {
        Visible                 = false;
    }
    feature point08 GC.Point
    {
        Visible                 = false;
    }
    feature point09 GC.Point
    {
        Visible                 = false;
    }
    feature point10 GC.Point
    {
        Visible                 = false;
    }
    feature point11 GC.Point
    {
        Visible                 = false;
    }
    feature point12 GC.Point
    {
        Visible                 = false;
    }
    feature point13 GC.Point
    {
        Visible                 = false;
    }
    feature point14 GC.Point
    {
        Visible                 = false;
    }
    feature point15 GC.Point
    {
        Visible                 = false;
    }
    feature point16 GC.Point
    {
        Visible                 = false;
    }
    feature point17 GC.Point
    {
        Visible                 = false;
    }
    feature point18 GC.Point
    {
        Visible                 = false;
    }
    feature point19 GC.Point
    {
        Visible                 = false;
    }
    feature point20 GC.Point
    {
        Visible                 = false;
    }
    feature point21 GC.Point
    {
        Visible                 = false;
    }
    feature point22 GC.Point
    {
        Visible                 = false;
    }
    feature point23 GC.Point
    {
        Visible                 = false;
    }
    feature point24 GC.Point
    {
        Visible                 = false;
    }
    feature point25 GC.Point
    {
        Visible                 = false;
    }
    feature point26 GC.Point
    {
        Visible                 = false;
    }
    feature point27 GC.Point
    {
        Visible                 = false;
    }
    feature point28 GC.Point
    {
        Visible                 = false;
    }
    feature point29 GC.Point
    {
        Visible                 = false;
    }
    feature point30 GC.Point
    {
        Visible                 = false;
    }
    feature point31 GC.Point
    {
        Visible                 = false;
    }
    feature point32 GC.Point
    {
        Visible                 = false;
    }
    feature point33 GC.Point
    {
        Visible                 = false;
    }
    feature point34 GC.Point
    {
        Visible                 = false;
    }
    feature point35 GC.Point
    {
        Visible                 = false;
    }
    feature point36 GC.Point
    {
        Visible                 = false;
    }
    feature point37 GC.Point
    {
        Visible                 = false;
    }
    feature point38 GC.Point
    {
        Visible                 = false;
    }
    feature point39 GC.Point
    {
        Visible                 = false;
    }
    feature point40 GC.Point
    {
        Visible                 = false;
    }
    feature point41 GC.Point
    {
        Visible                 = false;
    }
    feature point42 GC.Point
    {
        Visible                 = false;
    }
    feature point43 GC.Point
    {
        Visible                 = false;
    }
    feature point44 GC.Point
    {
        Visible                 = false;
    }
    feature point45 GC.Point
    {
        Visible                 = false;
    }
    feature point46 GC.Point
    {
        Visible                 = false;
    }
    feature point47 GC.Point
    {
        Visible                 = false;
    }
    feature point48 GC.Point
    {
        Visible                 = false;
    }
    feature point49 GC.Point
    {
        Surface                 = bsplineSurface01;
        U                       = Series(0,1,0.1);
        V                       = Series(0,1,0.1);
        HandlesVisible          = true;
        Replication             = ReplicationOption.AllCom-
binations;
    }
}

transaction modelBased "point grid on cloud"
{
    feature bsplineSurface01 GC.BSplineSurface
    {
        Visible                 = false;
    }
    feature polygon01 GC.Polygon
    {
        Points                  = point49;
    }
}

transaction modelBased "LOCAL01 4 points polygon 2
points 2 splines"
{
    feature bsplineCurve07 GC.BSplineCurve
    {
```



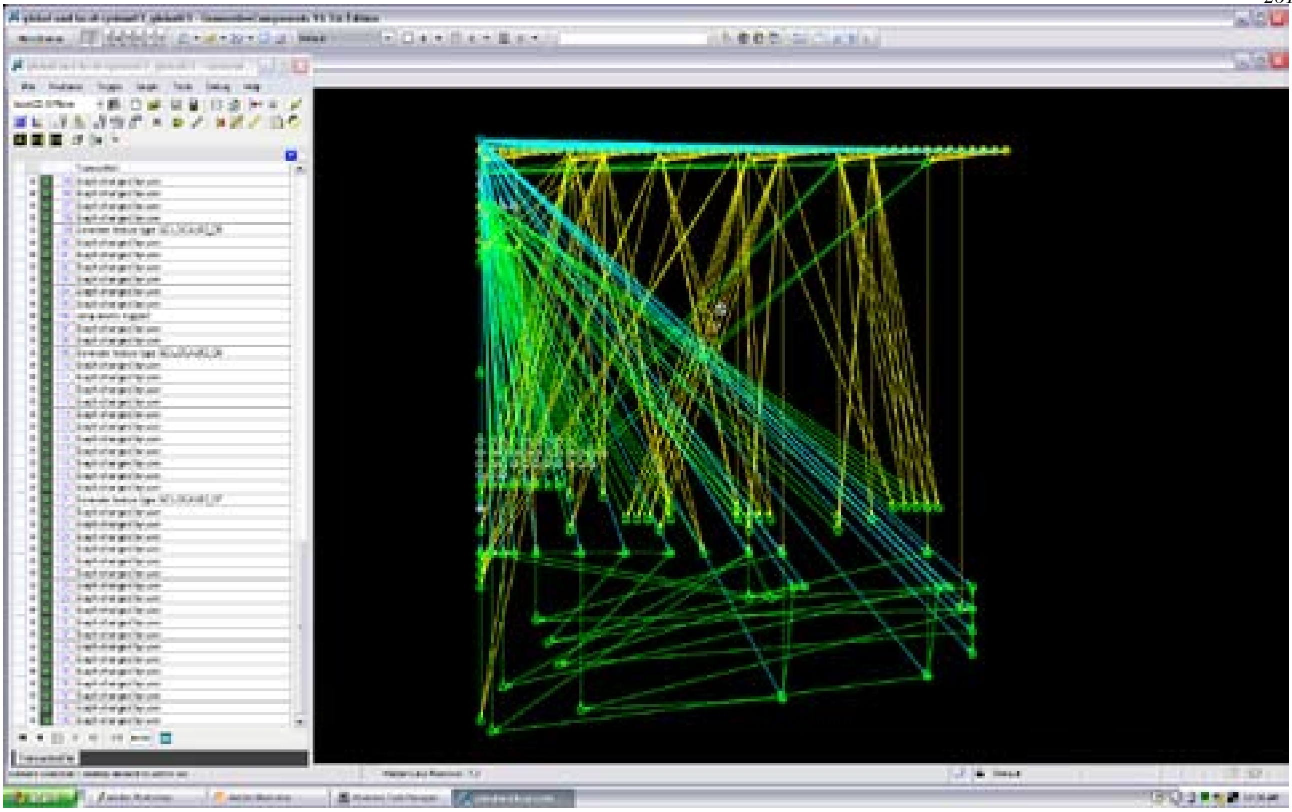


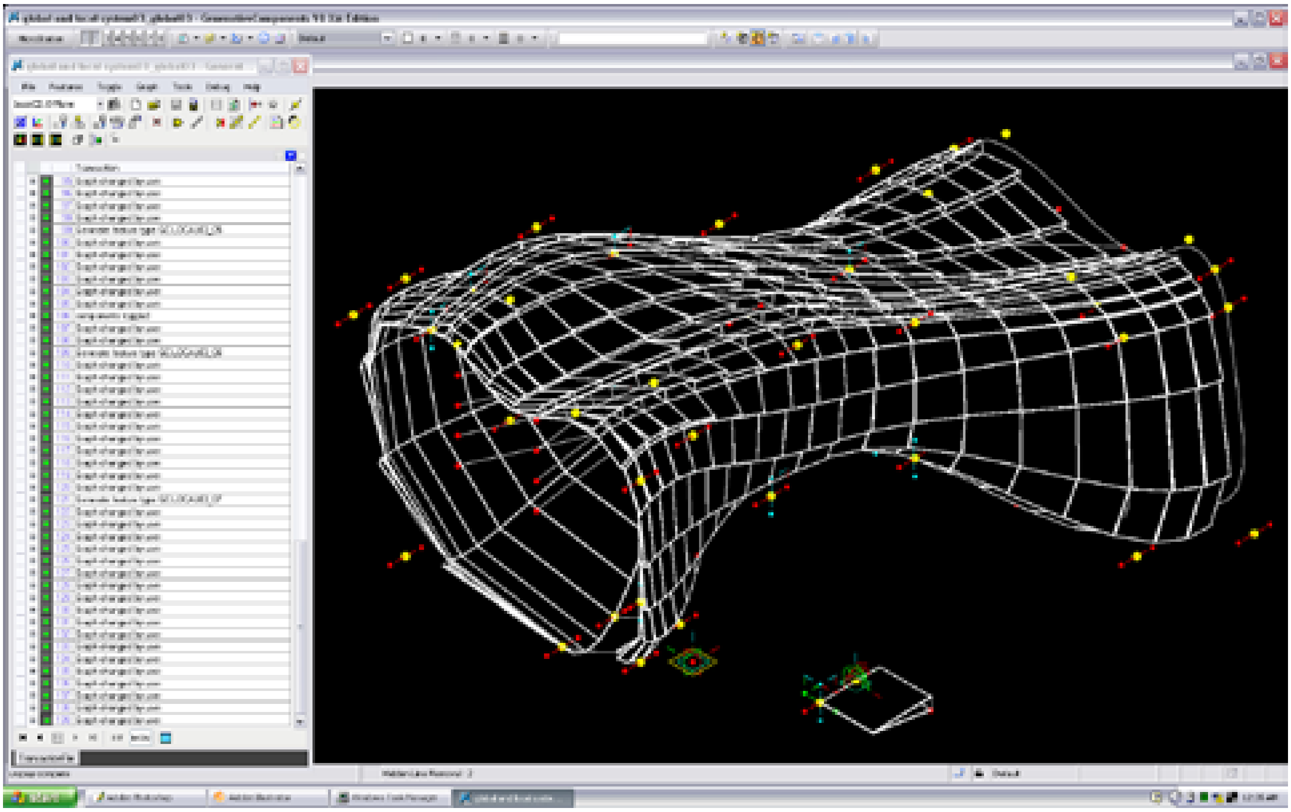
```
{
   feature bsplineCurve15 GC.BSplineCurve
   {
      Points                  = {point56,point57};
   }
   feature bsplineCurve16 GC.BSplineCurve
   {
      Points                  = {point59,point58};
   }
   feature bsplineSurface07 GC.BSplineSurface
   {
      Curves                  = {bsplineCurve07,bsplineCurve15};
   }
   feature bsplineSurface08 GC.BSplineSurface
   {
      Curves                  = {bsplineCurve16,bsplineCurve08};
   }
}

transaction generateFeatureType "Generate feature type GC.LOCAL01_02"
{
   type                    = GC.LOCAL01_02;
   inputProperties         = {
                           property double coordinateSystem01_U
                           {
                              originalName            = coordinateSystem01_U;
                              isOptional              = true;
                              defaultValue            = 0.691452521597676;
                           }
                           property double coordinateSystem01_V
                           {
                              originalName            = coordinateSystem01_V;
                              isOptional              = true;
                              defaultValue            = 0.193229221807763;
                           }
                           property GC.Polygon polygon02
                           {
                              feature                 = polygon02;
                              isReplicatable          = true;
                              isParentModel           = true;
                           }
                        };
   outputProperties        = {
                           property GC.BSplineCurve bsplineCurve07
                           {
                              feature                 = bsplineCurve07;
                              isDynamic               = true;
                           }
                           property GC.BSplineCurve bsplineCurve08
                           {
                              feature                 = bsplineCurve08;
                              isDynamic               = true;
                           }
                           property GC.BSplineCurve bsplineCurve13
                           {
                              feature                 = bsplineCurve13;
                              isDynamic               = true;
                           }
                           property GC.BSplineCurve bsplineCurve14
                           {
                              feature                 = bsplineCurve14;
                              isDynamic               = true;
                           }
                           property GC.BSplineCurve bsplineCurve15
                           {
                              feature                 = bsplineCurve15;
                              isDynamic               = true;
                           }
                           property GC.BSplineCurve bsplineCurve16
                           {
                              feature                 = bsplineCurve16;
                              isDynamic               = true;
                           }
                           property GC.BSplineSurface bsplineSurface02
                           {
                              feature                 = bsplineSurface02;
                              isConstruction          = true;
                              isDynamic               = true;
                           }
                           property GC.BSplineSurface bsplineSurface06
                           {
                              feature                 = bsplineSurface06;
                              isDynamic               = true;
                           }
                           property GC.BSplineSurface bsplineSurface07
                           {
                              feature                 = bsplineSurface07;
                              isDynamic               = true;
                           }
                           property GC.BSplineSurface bsplineSurface08
                           {
                              feature                 = bsplineSurface08;
                              isDynamic               = true;
                           }
                           property GC.CoordinateSystem coordinateSystem01
                           {
                              feature                 = coordinateSystem01;
                              isConstruction          = true;
                              isDynamic               = true;
                           }
                           property GC.Point point54
                           {
                              feature                 = point54;
                              isConstruction          = true;
                              isDynamic               = true;
                           }
                           property GC.Point point55
                           {
                              feature                 = point55;
                              isConstruction          = true;
                              isDynamic               = true;
                           }
                           property GC.Point point56
                           {
                              feature                 = point56;
                              isConstruction          = true;
                              isDynamic               = true;
                           }
                           property GC.Point point57
                           {
                              feature                 = point57;
                              isConstruction          = true;
                              isDynamic               = true;
                           }
                           property GC.Point point58
                           {
                              feature                 = point58;
                              isConstruction          = true;
                              isDynamic               = true;
                           }
                           property GC.Point point59
                           {
                              feature                 = point59;
                              isConstruction          = true;
                              isDynamic               = true;
                           }
                           property GC.Point point60
                           {
                              feature                 = point60;
                              isConstruction          = true;
                              isDynamic               = true;
                           }
                           property GC.Point point61
                           {
                              feature                 = point61;
                              isConstruction          = true;
                              isDynamic               = true;
                           }
                           property GC.Point point62
                           {
                              feature                 = point62;
                              isConstruction          = true;
                              isDynamic               = true;
                           }
                           property GC.Point point63
                           {
                              feature                 = point63;
                              isConstruction          = true;
                              isDynamic               = true;
                           }
                           property GC.Point point64
                           {
                              feature                 = point64;
                              isConstruction          = true;
                              isDynamic               = true;
                           }
                           property GC.Point point65
                           {
                              feature                 = point65;
                              isConstruction          = true;
                              isDynamic               = true;
                           }
                           property GC.Point point66
                           {
                              feature                 = point66;
                              isConstruction          = true;
                              isDynamic               = true;
                           }
                           property GC.Point point67
                           {
                              feature                 = point67;
                              isConstruction          = true;
                              isDynamic               = true;
                           }
                        };
}

transaction modelBased "Graph changed by user"
{
   feature local01_0201 GC.LOCAL01_02
   {
      polygon02               = polygon01;
   }
}

transaction modelBased "LOCAL01_03"
{
   deleteFeature local01_0201;
   feature point56 GC.Point
   {
      DistanceFromOrigin      = -0.3;
   }
   feature point57 GC.Point
   {
      DistanceFromOrigin      = -0.3;
   }
   feature point58 GC.Point
   {
      DistanceFromOrigin      = 0.3;
   }
   feature point59 GC.Point
   {
      DistanceFromOrigin      = 0.3;
   }
   feature point64 GC.Point
   {
      DistanceFromOrigin      = -0.3;
   }
   feature point65 GC.Point
   {
      DistanceFromOrigin      = -0.3;
   }
   feature point66 GC.Point
   {
      DistanceFromOrigin      = 0.3;
   }
   feature point67 GC.Point
   {
      DistanceFromOrigin      = 0.3;
   }
}

transaction generateFeatureType "Generate feature type
GC.LOCAL01_03"
{
   type                    = GC.LOCAL01_03;
   inputProperties         = {
                           property double coordinateSystem01_U
                           {
                              originalName            =
coordinateSystem01_U;
                              isOptional              = true;
                              defaultValue            =
0.691452521597676;
                           }
                           property double coordinateSystem01_V
                           {
                              originalName            =
coordinateSystem01_V;
                              isOptional              = true;
                              defaultValue            =
0.193229221807763;
                           }
                           property GC.Polygon polygon02
                           {
                              feature                 = polygon02;
                              isReplicatable          = true;
                              isParentModel           = true;
                           }
                        };
   outputProperties        = {
                           property GC.BSplineCurve
bsplineCurve07
                           {
                              feature                 = bsplineCurve07;
                              isDynamic               = true;
                           }
                           property GC.BSplineCurve
bsplineCurve08
                           {
                              feature                 = bsplineCurve08;
                              isDynamic               = true;
                           }
                           property GC.BSplineCurve
bsplineCurve13
                           {
                              feature                 = bsplineCurve13;
                              isDynamic               = true;
                           }
                           property GC.BSplineCurve
bsplineCurve14
                           {
                              feature                 = bsplineCurve14;
                              isDynamic               = true;
                           }
                           property GC.BSplineCurve
bsplineCurve15
                           {
                              feature                 = bsplineCurve15;
                              isDynamic               = true;
                           }
                           property GC.BSplineCurve
bsplineCurve16
                           {
                              feature                 = bsplineCurve16;
                              isDynamic               = true;
                           }
                           property GC.BSplineSurface
bsplineSurface02
                           {
                              feature                 = bsplineSurface02;
                              isConstruction          = true;
                              isDynamic               = true;
                           }
                           property GC.BSplineSurface
bsplineSurface06
                           {
                              feature                 = bsplineSurface06;
                              isDynamic               = true;
                           }
                           property GC.BSplineSurface
bsplineSurface07
                           {
                              feature                 = bsplineSurface07;
                              isDynamic               = true;
                           }
                           property GC.BSplineSurface
bsplineSurface08
                           {
                              feature                 = bsplineSurface08;
                              isDynamic               = true;
                           }
                           property GC.CoordinateSystem
coordinateSystem01
                           {
                              feature                 = coordinate-
System01;
                              isConstruction          = true;
                              isDynamic               = true;
                           }
                           property GC.Point point54
                           {
                              feature                 = point54;
                              isConstruction          = true;
                              isDynamic               = true;
                           }
                           property GC.Point point55
                           {
                              feature                 = point55;
                              isConstruction          = true;
                              isDynamic               = true;
                           }
                           property GC.Point point56
                           {
                              feature                 = point56;
                              isConstruction          = true;
                              isDynamic               = true;
                           }
                           property GC.Point point57
                           {
                              feature                 = point57;
                              isConstruction          = true;
                              isDynamic               = true;
                           }
                           property GC.Point point58
                           {
                              feature                 = point58;
                              isConstruction          = true;
                              isDynamic               = true;
                           }
                           property GC.Point point59
                           {
                              feature                 = point59;
                              isConstruction          = true;
                              isDynamic               = true;
                           }
                           property GC.Point point60
                           {
                              feature                 = point60;
                              isConstruction          = true;
                              isDynamic               = true;
                           }
                           property GC.Point point61
                           {
                              feature                 = point61;
                              isConstruction          = true;
                              isDynamic               = true;
                           }
                           property GC.Point point62
                           {
                              feature                 = point62;
                              isConstruction          = true;
                              isDynamic               = true;
                           }
                           property GC.Point point63
                           {
                              feature                 = point63;
                              isConstruction          = true;
                              isDynamic               = true;
                           }
                           property GC.Point point64
                           {
                              feature                 = point64;
                              isConstruction          = true;
                              isDynamic               = true;
                           }
                           property GC.Point point65
                           {
                              feature                 = point65;
                              isConstruction          = true;
                              isDynamic               = true;
                           }
                           property GC.Point point66
                           {
                              feature                 = point66;
                              isConstruction          = true;
                              isDynamic               = true;
                           }
                           property GC.Point point67
                           {
                              feature                 = point67;
                              isConstruction          = true;
                              isDynamic               = true;
                           }
                        };
}

transaction modelBased "Graph changed by user"
{
   feature local01_0301 GC.LOCAL01_03
   {
      polygon02               = polygon01;
   }
}

transaction modelBased "Prepare to generate feature type
GC.LOCAL01_03_02"
{
   deleteFeature local01_0301;
}

transaction generateFeatureType "Generate feature type
GC.LOCAL01_03_02"
{
   type                    = GC.LOCAL01_03_02;
   inputProperties         = {
                           property double
coordinateSystem01_U
                           {
                              originalName            =
coordinateSystem01_U;
                              isOptional              = true;
                              defaultValue            =
0.691452521597676;
                           }
                           property double
coordinateSystem01_V
                           {
                              originalName            =
coordinateSystem01_V;
                              isOptional              = true;
                              defaultValue            =
0.193229221807763;
                           }
                           property GC.Polygon polygon02
                           {
                              feature                 = polygon02;
                              isReplicatable          = true;
                              isParentModel           = true;
                           }
                        };
   outputProperties        = {
                           property GC.BSplineCurve
bsplineCurve07
                           {
                              feature                 =
bsplineCurve07;
                              isDynamic               = true;
                           }
                           property GC.BSplineCurve
bsplineCurve08
                           {
                              feature                 =
bsplineCurve08;
                              isDynamic               = true;
                           }
                           property GC.BSplineCurve
bsplineCurve13
                           {
                              feature                 =
bsplineCurve13;
                              isDynamic               = true;
                           }
                           property GC.BSplineCurve
bsplineCurve14
                           {
                              feature                 =
bsplineCurve14;
                              isDynamic               = true;
                           }
                           property GC.BSplineCurve
bsplineCurve15
                           {
                              feature                 =
bsplineCurve15;
                              isDynamic               = true;
                           }
                           property GC.BSplineCurve
bsplineCurve16
                           {
                              feature                 =
bsplineCurve16;
                              isDynamic               = true;
                           }
                           property GC.BSplineSurface
bsplineSurface02
                           {
                              feature                 =
bsplineSurface02;
                              isDynamic               = true;
                           }
                           property GC.BSplineSurface
bsplineSurface06
                           {
                              feature                 =
bsplineSurface06;
                              isDynamic               = true;
                           }
                           property GC.BSplineSurface
bsplineSurface07
```



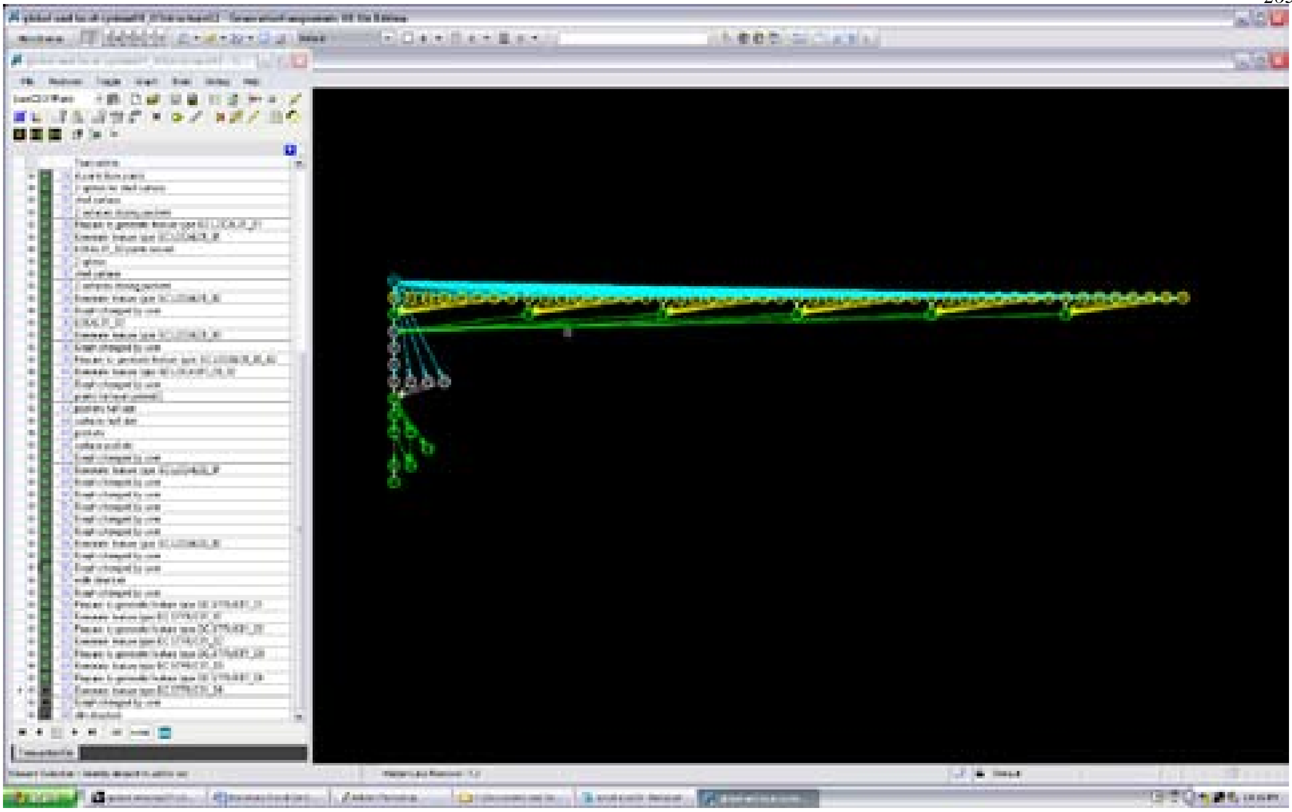


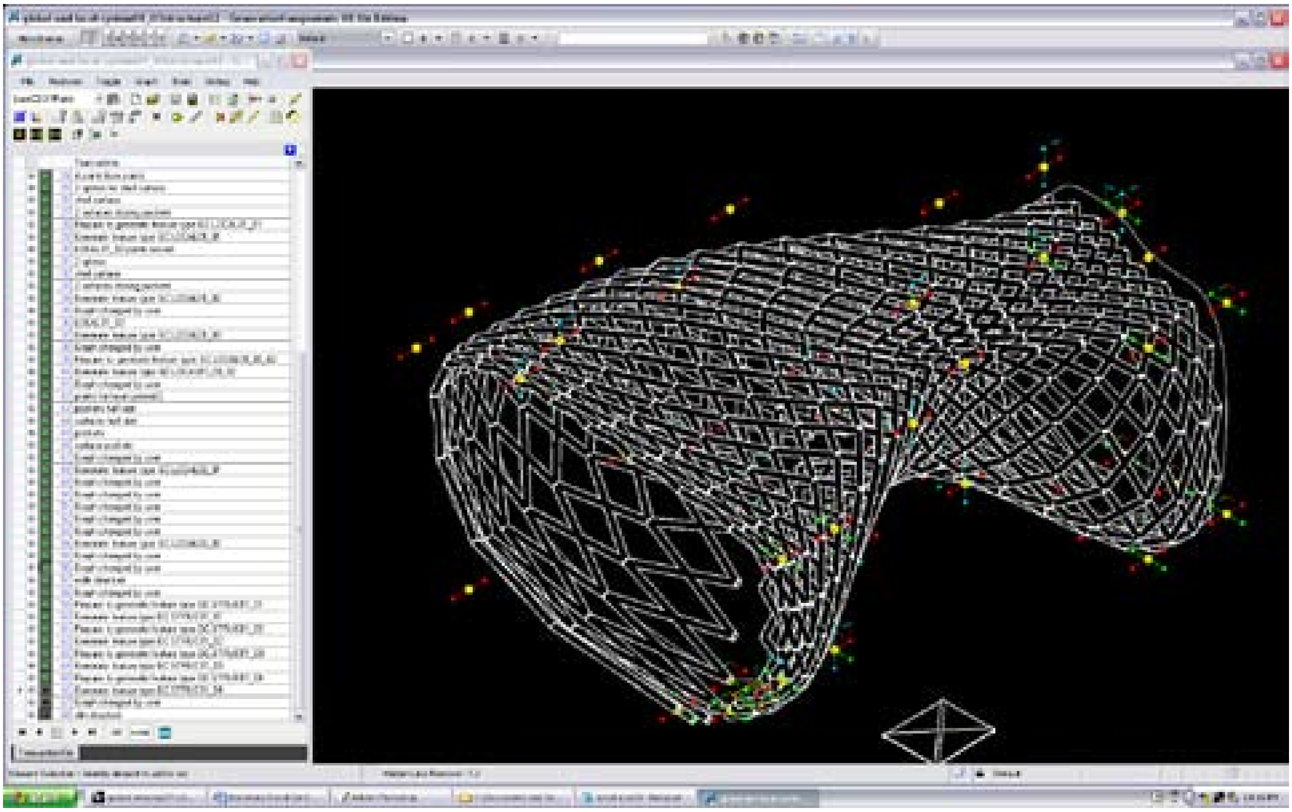
```
        Points                  = {polygon02.Vertices[0],polygon02.
Vertices[1]};
    }
    feature bsplineCurve08 GC.BSplineCurve
    {
        Points                  = {polygon02.Vertices[3],polygon02.
Vertices[2]};
    }
    feature point50 GC.Point
    {
        CoordinateSystem        = baseCS;
        XTranslation            = <free> (1.09941343836953);
        YTranslation            = <free> (-3.77750763269299);
        ZTranslation            = <free> (0.0);
        HandlesVisible          = true;
        Visible                 = false;
    }
    feature point51 GC.Point
    {
        CoordinateSystem        = baseCS;
        XTranslation            = <free> (3.40120448483751);
        YTranslation            = <free> (-3.74640588890597);
        ZTranslation            = <free> (0.0);
        HandlesVisible          = true;
        Visible                 = false;
    }
    feature point52 GC.Point
    {
        CoordinateSystem        = baseCS;
        XTranslation            = <free> (3.40120448483751);
        YTranslation            = <free> (-5.70581574748838);
        ZTranslation            = <free> (0.0);
        HandlesVisible          = true;
        Visible                 = false;
    }
    feature point53 GC.Point
    {
        CoordinateSystem        = baseCS;
        XTranslation            = <free> (1.09941343836953);
        YTranslation            = <free> (-5.79912097884945);
        ZTranslation            = <free> (0.0);
        HandlesVisible          = true;
        Visible                 = false;
    }
    feature point54 GC.Point
    {
        Curve                   = polygon02;
        T                       = 0.875;
        HandlesVisible          = true;
    }
    feature point55 GC.Point
    {
        Curve                   = polygon02;
        T                       = 0.375;
        HandlesVisible          = true;
    }
    feature polygon02 GC.Polygon
    {
        Vertices                = {point50,point51,point52,point53};
    }
}

transaction modelBased "surface"
{
    feature bsplineSurface02 GC.BSplineSurface
    {
        Curves                  = {bsplineCurve07,bsplineCurve08};
    }
}

transaction modelBased "coordinatesystem01"
{
    feature coordinateSystem01 GC.CoordinateSystem
    {
        Surface                 = bsplineSurface02;
        U                       = <free> (0.691452521597676);
        V                       = <free> (0.193229221807763);
        HandlesVisible          = true;
    }
}

transaction modelBased "4 points"
{
    feature point56 GC.Point
    {
        Origin                  = polygon02.Vertices[0];
        Direction               = coordinateSystem01.ZDirection;
        DistanceFromOrigin      = 0.3;
    }
    feature point57 GC.Point
    {
        Origin                  = polygon02.Vertices[3];
        Direction               = coordinateSystem01.ZDirection;
        DistanceFromOrigin      = -0.3;
    }
    feature point58 GC.Point
    {
        Origin                  = polygon02.Vertices[2];
        Direction               = coordinateSystem01.ZDirection;
        DistanceFromOrigin      = -0.3;
    }
    feature point59 GC.Point
    {
        Origin                  = polygon02.Vertices[1];
        Direction               = coordinateSystem01.ZDirection;
        DistanceFromOrigin      = 0.3;
    }
}

transaction modelBased "4 points on polygon"
{
    feature point60 GC.Point
    {
        Curve                   = polygon02;
        T                       = 0.80;
        HandlesVisible          = true;
    }
    feature point61 GC.Point
    {
        Curve                   = polygon02;
        T                       = 0.95;
        HandlesVisible          = true;
    }
    feature point62 GC.Point
    {
        Curve                   = polygon02;
        T                       = 0.30;
        HandlesVisible          = true;
    }
    feature point63 GC.Point
    {
        Curve                   = polygon02;
        T                       = 0.45;
        HandlesVisible          = true;
    }
}

transaction modelBased "4 points from points"
{
    feature point64 GC.Point
    {
        Origin                  = point61;
        Direction               = coordinateSystem01.ZDirection;
        DistanceFromOrigin      = 0.3;
    }
    feature point65 GC.Point
    {
        Origin                  = point60;
        Direction               = coordinateSystem01.ZDirection;
        DistanceFromOrigin      = -0.3;
    }
    feature point66 GC.Point
    {
        Origin                  = point62;
        Direction               = coordinateSystem01.ZDirection;
        DistanceFromOrigin      = 0.3;
    }
    feature point67 GC.Point
    {
        Origin                  = point63;
        Direction               = coordinateSystem01.ZDirection;
        DistanceFromOrigin      = -0.3;
    }
}

transaction modelBased "2 splines for shell surface"
{
    feature bsplineCurve09 GC.BSplineCurve
    {
        Poles                   = {point56,point64,point54,point
65,point57};
        Order                   = 3;
    }
    feature bsplineCurve10 GC.BSplineCurve
    {
        Poles                   = {point59,point66,point55,point
67,point58};
        Order                   = 3;
    }
}

transaction modelBased "shell surface"
{
    feature bsplineSurface03 GC.BSplineSurface
    {
        Curves                  = {bsplineCurve09,bsplineCurve10};
    }
}

transaction modelBased "2 surfaces closing pockets"
{
    feature bsplineCurve11 GC.BSplineCurve
    {
        Points                  = {point56,point59};
    }
    feature bsplineCurve12 GC.BSplineCurve
    {
        Points                  = {point57,point58};
    }
    feature bsplineSurface04 GC.BSplineSurface
    {
        Curves                  = {bsplineCurve08,bsplineCurve12};
    }
    feature bsplineSurface05 GC.BSplineSurface
    {
        Curves                  = {bsplineCurve07,bsplineCurve11};
    }
}

transaction modelBased "Prepare to generate feature type
GC.LOCAL01_01"
{
    feature point55 GC.Point
    {
        Visible                 = false;
    }
    feature point57 GC.Point
    {
        SymbolXY                = {103, 118};
    }
}

transaction generateFeatureType "Generate feature type
GC.LOCAL01_01"
{
    type                        = GC.LOCAL01_01;
    inputProperties             = {
                                property double coordinateSystem01_U
                                {
                                    originalName        =
coordinateSystem01_U;
                                    isOptional          = true;
                                    defaultValue        =
0.691452521597676;
                                }
                                property double coordinateSystem01_V
                                {
                                    originalName        =
coordinateSystem01_V;
                                    isOptional          = true;
                                    defaultValue        =
0.193229221807763;
                                }
                                property GC.Polygon polygon02
                                {
                                    feature             = polygon02;
                                    isReplicatable      = true;
                                    isParentModel       = true;
                                }
                            };
    outputProperties            = {
                                property GC.BSplineCurve
bsplineCurve07
                                {
                                    feature             = bsplineCurve07;
                                    isDynamic           = true;
                                }
                                property GC.BSplineCurve
bsplineCurve08
                                {
                                    feature             =
bsplineCurve08;
                                    isDynamic           = true;
                                }
                                property GC.BSplineCurve
bsplineCurve09
                                {
                                    feature             =
bsplineCurve09;
                                    isDynamic           = true;
                                }
                                property GC.BSplineCurve
bsplineCurve10
                                {
                                    feature             =
bsplineCurve10;
                                    isDynamic           = true;
                                }
                                property GC.BSplineCurve
bsplineCurve11
                                {
                                    feature             =
bsplineCurve11;
                                    isDynamic           = true;
                                }
                                property GC.BSplineCurve
bsplineCurve12
                                {
                                    feature             =
bsplineCurve12;
                                    isDynamic           = true;
                                }
                                property GC.BSplineSurface
bsplineSurface02
                                {
                                    feature             =
bsplineSurface02;
                                    isConstruction      = true;
                                    isDynamic           = true;
                                }
                                property GC.BSplineSurface
bsplineSurface03
                                {
                                    feature             =
bsplineSurface03;
                                    isDynamic           = true;
                                }
                                property GC.BSplineSurface
bsplineSurface04
                                {
                                    feature             =
bsplineSurface04;
                                    isDynamic           = true;
                                }
                                property GC.BSplineSurface
bsplineSurface05
                                {
                                    feature             =
bsplineSurface05;
                                    isDynamic           = true;
                                }
                                property GC.CoordinateSystem
coordinateSystem01
                                {
                                    feature             = coordi-
nateSystem01;
                                    isConstruction      = true;
                                    isDynamic           = true;
                                }
                                property GC.Point point54
                                {
                                    feature             = point54;
                                    isConstruction      = true;
                                    isDynamic           = true;
                                }
                                property GC.Point point56
                                {
                                    feature             = point56;
                                    isConstruction      = true;
                                    isDynamic           = true;
                                }
                                property GC.Point point57
                                {
                                    feature             = point57;
                                    isConstruction      = true;
                                    isDynamic           = true;
                                }
                                property GC.Point point58
                                {
                                    feature             = point58;
                                    isConstruction      = true;
                                    isDynamic           = true;
                                }
                                property GC.Point point59
                                {
                                    feature             = point59;
                                    isConstruction      = true;
                                    isDynamic           = true;
                                }
                                property GC.Point point60
                                {
                                    feature             = point60;
                                    isConstruction      = true;
                                    isDynamic           = true;
                                }
                                property GC.Point point61
                                {
                                    feature             = point61;
                                    isConstruction      = true;
                                    isDynamic           = true;
                                }
                                property GC.Point point62
                                {
                                    feature             = point62;
                                    isConstruction      = true;
                                    isDynamic           = true;
                                }
                                property GC.Point point63
                                {
                                    feature             = point63;
                                    isConstruction      = true;
                                    isDynamic           = true;
                                }
                                property GC.Point point64
                                {
                                    feature             = point64;
                                    isConstruction      = true;
                                    isDynamic           = true;
                                }
                                property GC.Point point65
                                {
                                    feature             =
point65;
                                    isConstruction      =
true;
                                    isDynamic           =
true;
                                }
                                property GC.Point point66
                                {
                                    feature             =
point66;
                                    isConstruction      =
true;
                                    isDynamic           =
true;
                                }
                                property GC.Point point67
                                {
                                    feature             =
point67;
                                    isConstruction      =
true;
                                    isDynamic           =
true;
                                }
                            };
    internalProperties          = {
                                property GC.Point point55
                                {
                                    feature             =
point55;
                                    isConstruction      =
true;
                                    isDynamic           =
true;
                                }
                            };
}

transaction modelBased "LOCAL01_02 points
moved"
{
    deleteFeature bsplineCurve09;
    deleteFeature bsplineCurve10;
    deleteFeature bsplineCurve11;
    deleteFeature bsplineCurve12;
    deleteFeature bsplineSurface03;
    deleteFeature bsplineSurface04;
    deleteFeature bsplineSurface05;
    feature bsplineCurve07 GC.BSplineCurve
    {
        Points                  = {polygon02.
Vertices[0],polygon02.Vertices[3]};
    }
    feature bsplineCurve08 GC.BSplineCurve
    {
        Points                  = {polygon02.
Vertices[1],polygon02.Vertices[2]};
    }
    feature point54 GC.Point
    {
        T                       = 0.125;
    }
    feature point55 GC.Point
    {
        T                       = 0.625;
        Visible                 = true;
    }
    feature point57 GC.Point
    {
        DistanceFromOrigin      = 0.3;
    }
    feature point59 GC.Point
    {
        DistanceFromOrigin      = -0.3;
    }
    feature point60 GC.Point
    {
        T                       = 0.7;
    }
    feature point61 GC.Point
    {
        T                       = 0.05;
    }
    feature point62 GC.Point
    {
        T                       = 0.20;
    }
    feature point63 GC.Point
    {
        T                       = 0.55;
    }
    feature point65 GC.Point
    {
        DistanceFromOrigin      = 0.3;
    }
    feature point66 GC.Point
    {
        DistanceFromOrigin      = -0.3;
    }
}

transaction modelBased "2 splines"
{
    feature bsplineCurve13 GC.BSplineCurve
    {
        Poles                   = {point56,point64,point54
,point66,point59};
        Order                   = 3;
    }
    feature bsplineCurve14 GC.BSplineCurve
    {
        Poles                   = {point57,point65,point55
,point67,point58};
        Order                   = 3;
    }
}

transaction modelBased "shell surface"
{
    feature bsplineSurface06 GC.BSplineSurface
    {
        Curves                  = {bsplineCurve13,bsp
lineCurve14};
    }
}

transaction modelBased "2 surfaces closing
pockets"
```





```
transaction modelBased “8 points”
{
    feature point01 GC.Point
    {
        CoordinateSystem          = baseCS;
        XTranslation              = 1;
        YTranslation              = 6;
        ZTranslation              = 5;
        HandlesVisible            = true;
    }
    feature point02 GC.Point
    {
        CoordinateSystem          = baseCS;
        XTranslation              = 1;
        YTranslation              = 4;
        ZTranslation              = 5;
        HandlesVisible            = true;
    }
    feature point03 GC.Point
    {
        CoordinateSystem          = baseCS;
        XTranslation              = <free> (1);
        YTranslation              = <free> (2);
        ZTranslation              = <free> (5);
        HandlesVisible            = true;
    }
    feature point04 GC.Point
    {
        CoordinateSystem          = baseCS;
        XTranslation              = 1;
        YTranslation              = 0;
        ZTranslation              = 5;
        HandlesVisible            = true;
    }
    feature point05 GC.Point
    {
        CoordinateSystem          = baseCS;
        XTranslation              = <free> (1);
        YTranslation              = <free> (6);
        ZTranslation              = <free> (0.0);
        HandlesVisible            = true;
    }
    feature point06 GC.Point
    {
        CoordinateSystem          = baseCS;
        XTranslation              = <free> (1);
        YTranslation              = <free> (4);
        ZTranslation              = <free> (0.0);
        HandlesVisible            = true;
    }
    feature point07 GC.Point
    {
        CoordinateSystem          = baseCS;
        XTranslation              = <free> (1);
        YTranslation              = <free> (2);
        ZTranslation              = <free> (0.0);
        HandlesVisible            = true;
    }
    feature point08 GC.Point
    {
        CoordinateSystem          = baseCS;
        XTranslation              = <free> (1);
        YTranslation              = <free> (0);
        ZTranslation              = <free> (0.0);
        HandlesVisible            = true;
    }
}

transaction modelBased “Graph changed by user”
{
    feature point01 GC.Point
    {
        XTranslation              = <free> (1);
        YTranslation              = <free> (6);
        ZTranslation              = <free> (5);
    }
    feature point02 GC.Point
    {
        XTranslation              = <free> (1);
        YTranslation              = <free> (4);
        ZTranslation              = <free> (5);
    }
    feature point04 GC.Point
    {
        XTranslation              = <free> (1);
        YTranslation              = <free> (0);
        ZTranslation              = <free> (5);
    }
}

transaction modelBased “8 points”
{
    feature point09 GC.Point
    {
        CoordinateSystem          = baseCS;
        XTranslation              = <free> (3);
        YTranslation              = <free> (6);
        ZTranslation              = <free> (5);
    }
    feature point10 GC.Point
    {
        CoordinateSystem          = baseCS;
        XTranslation              = <free> (3);
        YTranslation              = <free> (4);
        ZTranslation              = <free> (5);
    }
    feature point11 GC.Point
    {
        CoordinateSystem          = baseCS;
        XTranslation              = <free> (3);
        YTranslation              = <free> (2);
        ZTranslation              = <free> (5);
    }
    feature point12 GC.Point
    {
        CoordinateSystem          = baseCS;
        XTranslation              = <free> (3);
        YTranslation              = <free> (0);
        ZTranslation              = <free> (5);
    }
    feature point13 GC.Point
    {
        CoordinateSystem          = baseCS;
        XTranslation              = <free> (3);
        YTranslation              = <free> (6);
        ZTranslation              = <free> (0.0);
    }
    feature point14 GC.Point
    {
        CoordinateSystem          = baseCS;
        XTranslation              = <free> (3);
        YTranslation              = <free> (4);
        ZTranslation              = <free> (0.0);
    }
    feature point15 GC.Point
    {
        CoordinateSystem          = baseCS;
        XTranslation              = <free> (3);
        YTranslation              = <free> (2);
        ZTranslation              = <free> (0.0);
    }
    feature point16 GC.Point
    {   }
    feature point05 GC.Point
    {
        Visible                   = false;
    }
    feature point06 GC.Point
    {
        Visible                   = false;
    }
    feature point07 GC.Point
    {
        Visible                   = false;
    }
    feature point08 GC.Point
    {
        Visible                   = false;
    }
    feature point09 GC.Point
    {
        Visible                   = false;
    }
    feature point10 GC.Point
    {
        Visible                   = false;
    }
    feature point11 GC.Point
    {
        Visible                   = false;
    }
    feature point12 GC.Point
    {
        Visible                   = false;
    }
    feature point13 GC.Point
    {
        Visible                   = false;
    }
    feature point14 GC.Point
    {
        Visible                   = false;
    }
    feature point15 GC.Point
    {
        Visible                   = false;
    }
    feature point16 GC.Point
    {
        Visible                   = false;
    }
    feature point17 GC.Point
    {
        Visible                   = false;
    }
    feature point18 GC.Point
    {
        Visible                   = false;
    }
    feature point19 GC.Point
    {
        Visible                   = false;
    }
    feature point20 GC.Point
    {
        Visible                   = false;
    }
    feature point21 GC.Point
    {
        Visible                   = false;
    }
    feature point22 GC.Point
    {
        Visible                   = false;
    }
    feature point23 GC.Point
    {
        Visible                   = false;
    }
    feature point24 GC.Point
    {
        Visible                   = false;
    }
    feature point25 GC.Point
    {
        Visible                   = false;
    }
    feature point26 GC.Point
    {
        Visible                   = false;
    }
    feature point27 GC.Point
    {
        Visible                   = false;
    }
    feature point28 GC.Point
    {
        Visible                   = false;
    }
    feature point29 GC.Point
    {
        Visible                   = false;
    }
    feature point30 GC.Point
    {
        Visible                   = false;
    }
    feature point31 GC.Point
    {
        Visible                   = false;
    }
    feature point32 GC.Point
    {
        Visible                   = false;
    }
    feature point33 GC.Point
    {
        Visible                   = false;
    }
    feature point34 GC.Point
    {
        Visible                   = false;
    }
    feature point35 GC.Point
    {
        Visible                   = false;
    }
    feature point36 GC.Point
    {
        Visible                   = false;
    }
    feature point37 GC.Point
    {
        Visible                   = false;
    }
    feature point38 GC.Point
    {
        Visible                   = false;
    }
    feature point39 GC.Point
    {
        Visible                   = false;
    }
    feature point40 GC.Point
    {
        Visible                   = false;
    }
    feature point41 GC.Point
    {
        Visible                   = false;
    }
    feature point42 GC.Point
    {
        Visible                   = false;
    }
    feature point43 GC.Point
    {
        Visible                   = false;
    }
    feature point44 GC.Point
    {
        Visible                   = false;
    }
    feature point45 GC.Point
    {
        Visible                   = false;
    }
    feature point46 GC.Point
    {
        Visible                   = false;
    }
    feature point47 GC.Point
    {
        Visible                   = false;
    }
    feature point48 GC.Point
    {
        Visible                   = false;
    }
    feature point49 GC.Point
    {
        Surface                   = bsplineSurface01;
        U                         = Series(0,1,0.1);
        V                         = Series(0,1,0.1);
        HandlesVisible            = true;
        Replication               = ReplicationOption.AllCombinations;
    }
}

transaction modelBased “point grid on cloud”
{
    feature bsplineSurface01 GC.BSplineSurface
    {
        Visible                   = false;
    }
    feature polygon01 GC.Polygon
    {
        Points                    = point49;
    }
}

transaction modelBased “LOCAL01 4 points polygon 2 points 2 splines”
{
    feature bsplineCurve07 GC.BSplineCurve
    {
        Points                    = {polygon02.Vertices[0],polygon02.Vertices[1]};
    }
    feature bsplineCurve08 GC.BSplineCurve
    {
        Points                    = {polygon02.Vertices[3],polygon02.Vertices[2]};
    }
    feature point50 GC.Point
    {
        CoordinateSystem          = baseCS;
        XTranslation              = <free> (1.09941343836953);
        YTranslation              = <free> (-3.77750763269299);
        ZTranslation              = <free> (0.0);
        HandlesVisible            = true;
        Visible                   = false;
    }
    feature point51 GC.Point
    {
        CoordinateSystem          = baseCS;
        XTranslation              = <free> (3.40120448483751);
        YTranslation              = <free> (-3.74640588890597);
        ZTranslation              = <free> (0.0);
        HandlesVisible            = true;
        Visible                   = false;
    }
    feature point52 GC.Point
    {
        CoordinateSystem          = baseCS;
        XTranslation              = <free> (3.40120448483751);
        YTranslation              = <free> (-5.70581574748838);
        ZTranslation              = <free> (0.0);
        HandlesVisible            = true;
        Visible                   = false;
    }
    feature point53 GC.Point
    {
        CoordinateSystem          = baseCS;
        XTranslation              = <free> (1.09941343836953);
        YTranslation              = <free> (-5.79912097884945);
        ZTranslation              = <free> (0.0);
        HandlesVisible            = true;
        Visible                   = false;
    }
    feature point54 GC.Point
    {
        Curve                     = polygon02;
        T                         = 0.875;
        HandlesVisible            = true;
    }
    feature point55 GC.Point
    {
        Curve                     = polygon02;
        T                         = 0.375;
        HandlesVisible            = true;
    }
    feature polygon02 GC.Polygon
    {
        Vertices                  = {point50,point51,point52,point53};
    }
}

transaction modelBased “surface”
{
    feature bsplineSurface02 GC.BSplineSurface
    {
        Curves                    = {bsplineCurve07,bsplineCurve08};
    }
}

transaction modelBased “coordinatesystem01”
{
    feature coordinateSystem01 GC.CoordinateSystem
    {
        Surface                   = bsplineSurface02;
        U                         = <free> (0.691452521597676);
        V                         = <free> (0.193229221807763);
        HandlesVisible            = true;
    }
}

transaction modelBased “4 points”
{
    feature point56 GC.Point
    {
        Origin                    = polygon02.Vertices[0];
        Direction                 = coordinateSystem01.ZDirection;
        DistanceFromOrigin        = 0.3;
    }
    feature point57 GC.Point
    {
        Origin                    = polygon02.Vertices[3];
        Direction                 = coordinateSystem01.ZDirection;
        DistanceFromOrigin        = -0.3;
    }
    feature point58 GC.Point
    {
        Origin                    = polygon02.Vertices[2];
        Direction                 = coordinateSystem01.ZDirection;
        DistanceFromOrigin        = -0.3;
    }
    feature point59 GC.Point
    {
        Origin                    = polygon02.Vertices[1];
        Direction                 = coordinateSystem01.ZDirection;
        DistanceFromOrigin        = 0.3;
    }
}

transaction modelBased “4 points on polygon”
{
    feature point60 GC.Point
    {
        Curve                     = polygon02;
        T                         = 0.80;
        HandlesVisible            = true;
    }
    feature point61 GC.Point
    {
        Curve                     = polygon02;
        T                         = 0.95;
        HandlesVisible            = true;
    }
    feature point62 GC.Point
    {
        Curve                     = polygon02;
        T                         = 0.30;
        HandlesVisible            = true;
    }
    feature point63 GC.Point
    {
        Curve                     = polygon02;
        T                         = 0.45;
        HandlesVisible            = true;
    }
}

transaction modelBased “4 points from points”
{
    feature point64 GC.Point
    {
        Origin                    = point61;
        Direction                 = coordinateSystem01.ZDirection;
        DistanceFromOrigin        = 0.3;
    }
    feature point65 GC.Point
    {
        Origin                    = point60;
        Direction                 = coordinateSystem01.ZDirection;
        DistanceFromOrigin        = -0.3;
    }
    feature point66 GC.Point
    {
        Origin                    = point62;
        Direction                 = coordinateSystem01.ZDirection;
        DistanceFromOrigin        = 0.3;
    }
    feature point67 GC.Point
    {
        Origin                    = point63;
        Direction                 = coordinateSystem01.ZDirection;
        DistanceFromOrigin        = -0.3;
    }
}

transaction modelBased “2 splines for shell surface”
{
    feature bsplineCurve09 GC.BSplineCurve
    {
        Poles                     = {point56,point64,point54,point65,point57};
        Order                     = 3;
    }
    feature bsplineCurve10 GC.BSplineCurve
    {
        Poles                     = {point59,point66,point55,point67,point58};
        Order                     = 3;
    }
}

transaction modelBased “shell surface”
{
    feature bsplineSurface03 GC.BSplineSurface
    {
        Curves                    = {bsplineCurve09,bsplineCurve10};
    }
}

transaction modelBased “2 surfaces closing pockets”
{
    feature bsplineCurve11 GC.BSplineCurve
    {
        Points                    = {point56,point59};
    }
    feature bsplineCurve12 GC.BSplineCurve
    {
        Points                    = {point57,point58};
    }
    feature bsplineSurface04 GC.BSplineSurface
    {
        Curves                    = {bsplineCurve08,bsplineCurve12};
    }
    feature bsplineSurface05 GC.BSplineSurface
    {
        Curves                    = {bsplineCurve07,bsplineCurve11};
    }
}

transaction modelBased “Prepare to generate feature type GC.LOCAL01_01”
{
    feature point55 GC.Point
    {
        Visible                   = false;
    }
    feature point57 GC.Point
    {
        SymbolXY                  = {103, 118};
    }
}

transaction generateFeatureType “Generate feature type GC.LOCAL01_01”
{
    type                          = GC.LOCAL01_01;
    inputProperties               = {
                                    property double coordinateSystem01_U
```



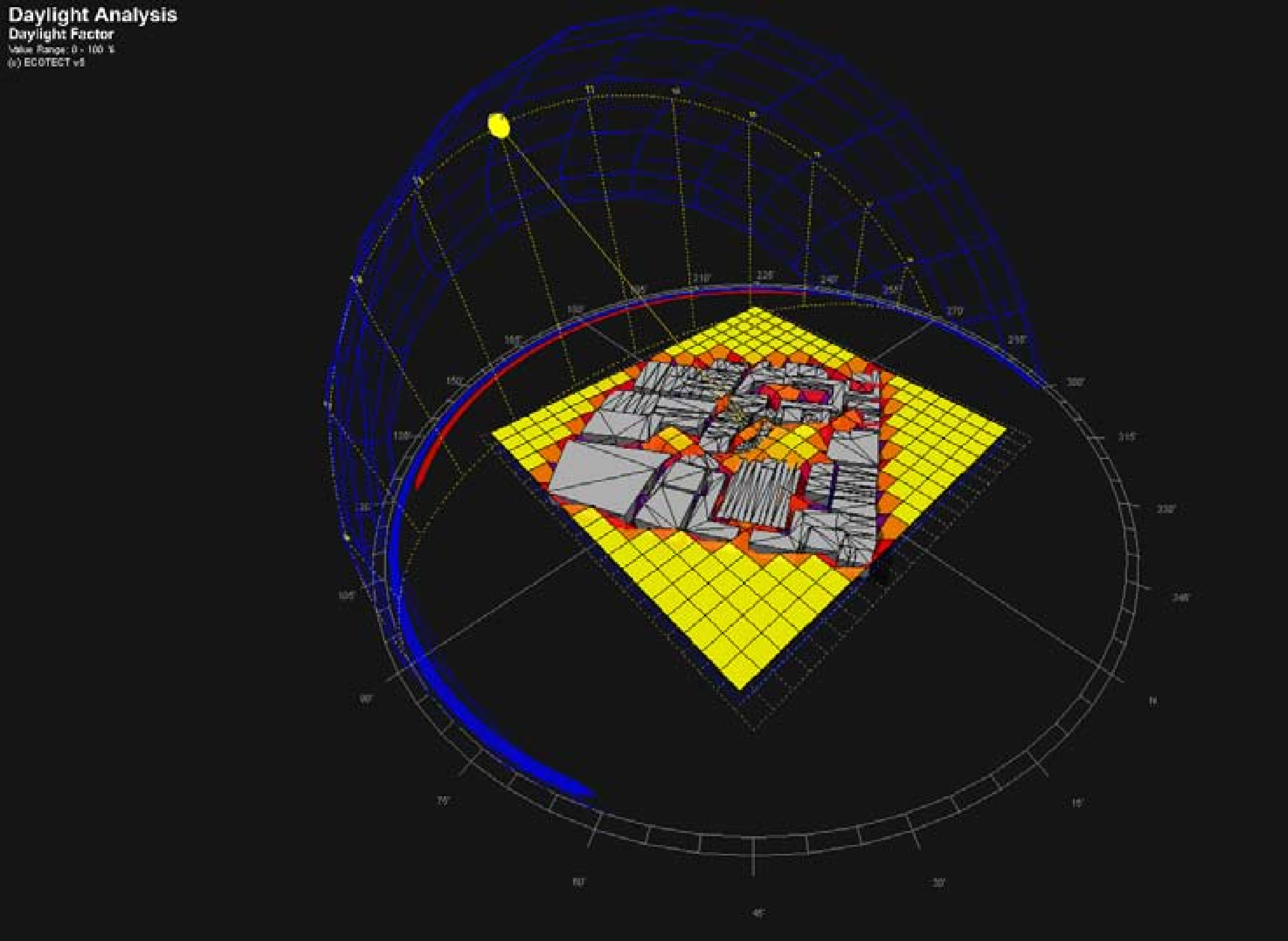


9.4 ECOTECT SIMULATION SCHEMES

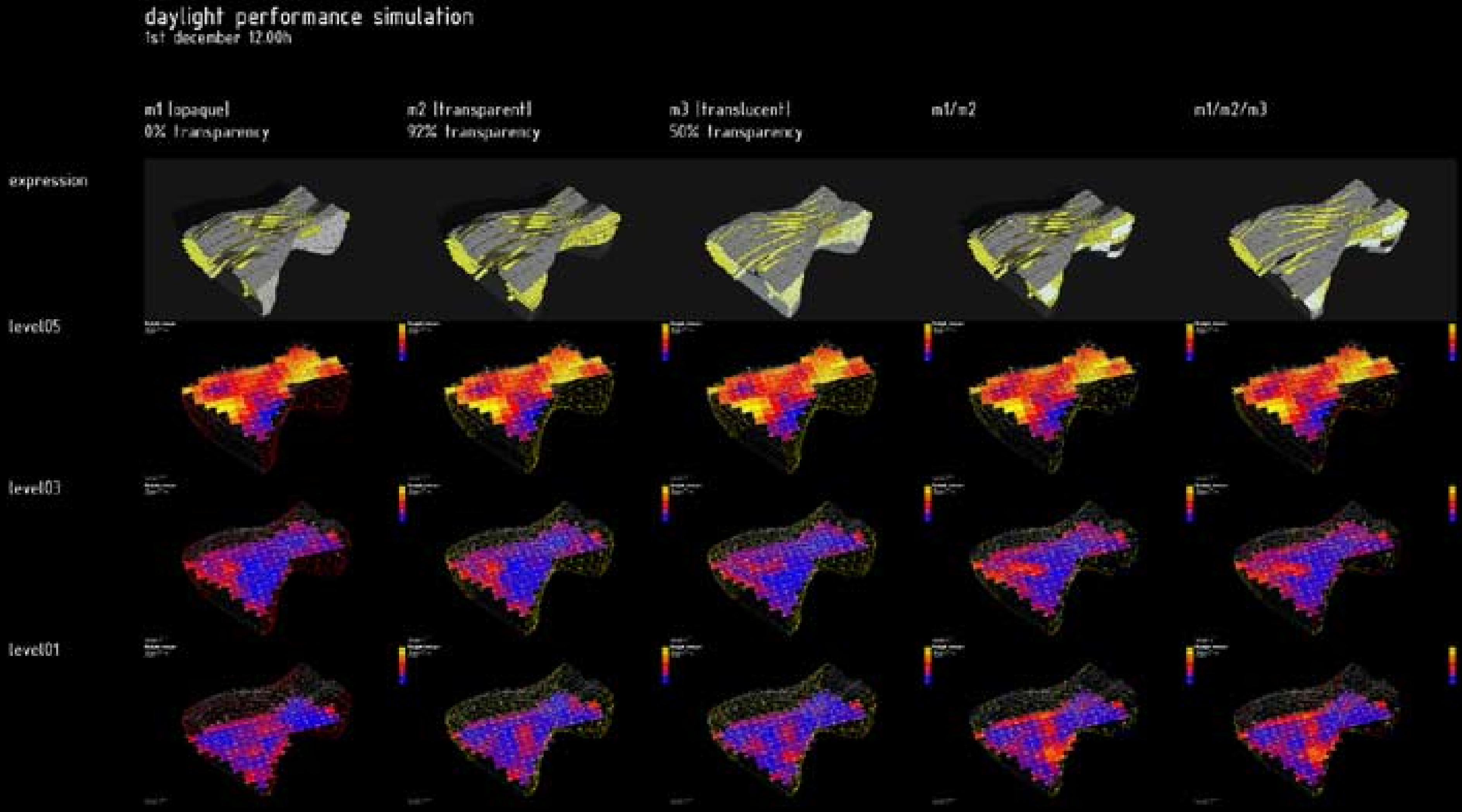
The following pages includes a selection of simulations which have guided the design forwards.

1. Daylight study of topology study
2. Daylight simulations of Design I, with different transparencies with data from summer and winter periods.
3. Daylight simulation of Design II paneling organization and new parametric organization.
4. Daylight study of Design III with colour properties
5. Cumulative simulation of East and West facades, with final daylight simulations

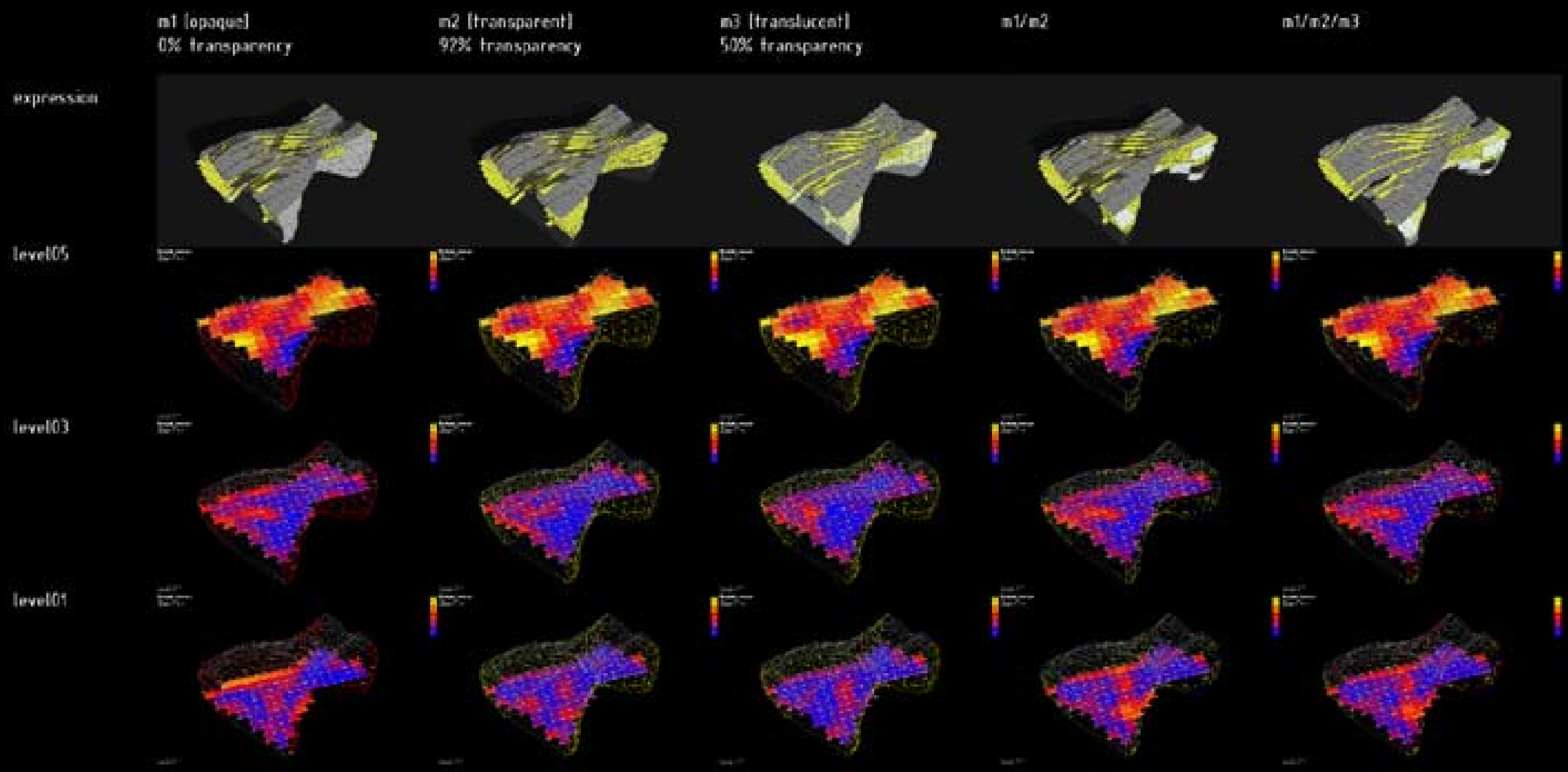
1. Daylight study of topology study


Daylight Analysis
Daylight Factor
Value Range: 0 - 100 %
(c) ECOTECT v5

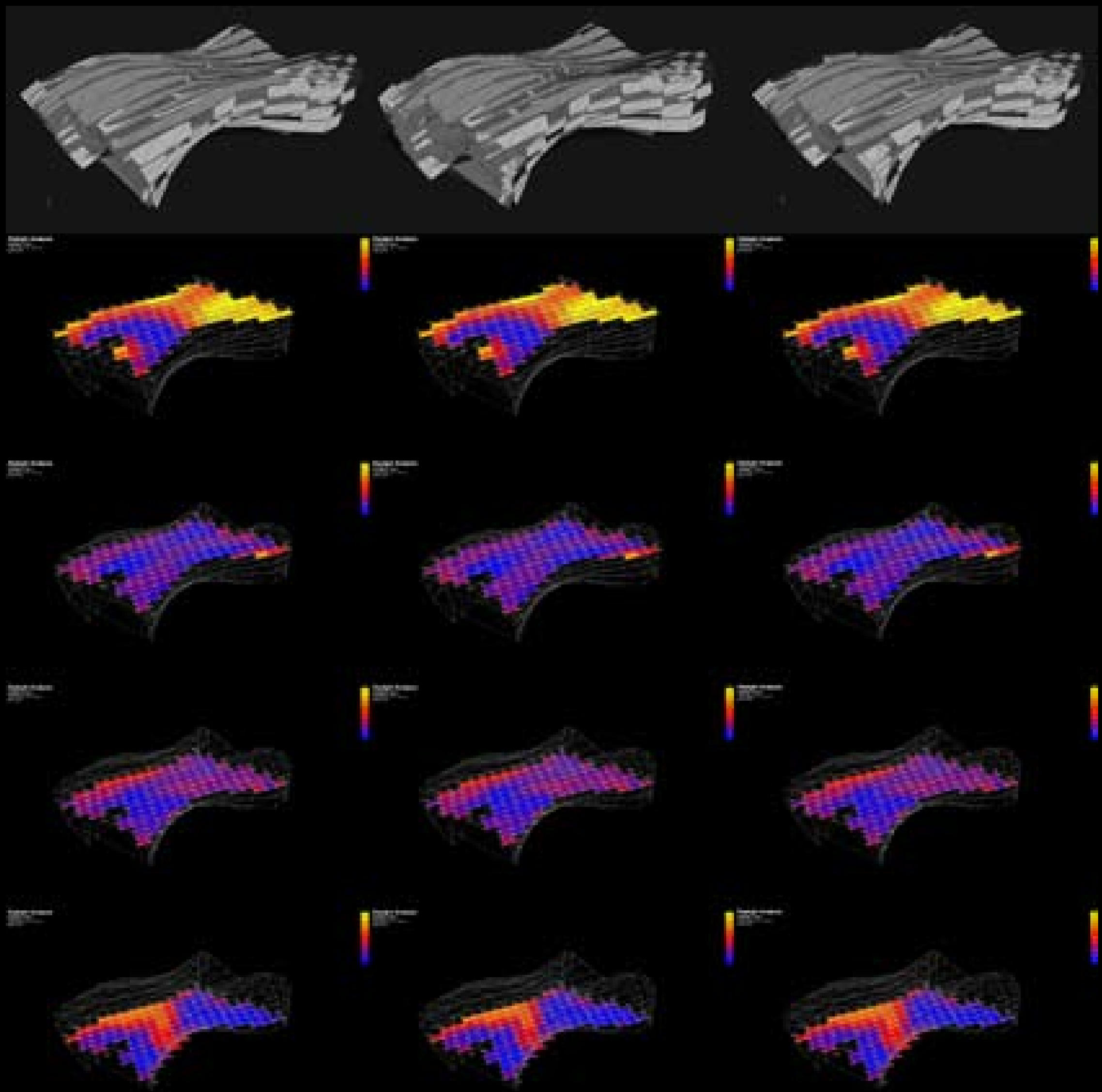
2. Daylight simulations of Design I, with different transparencies with data from summer



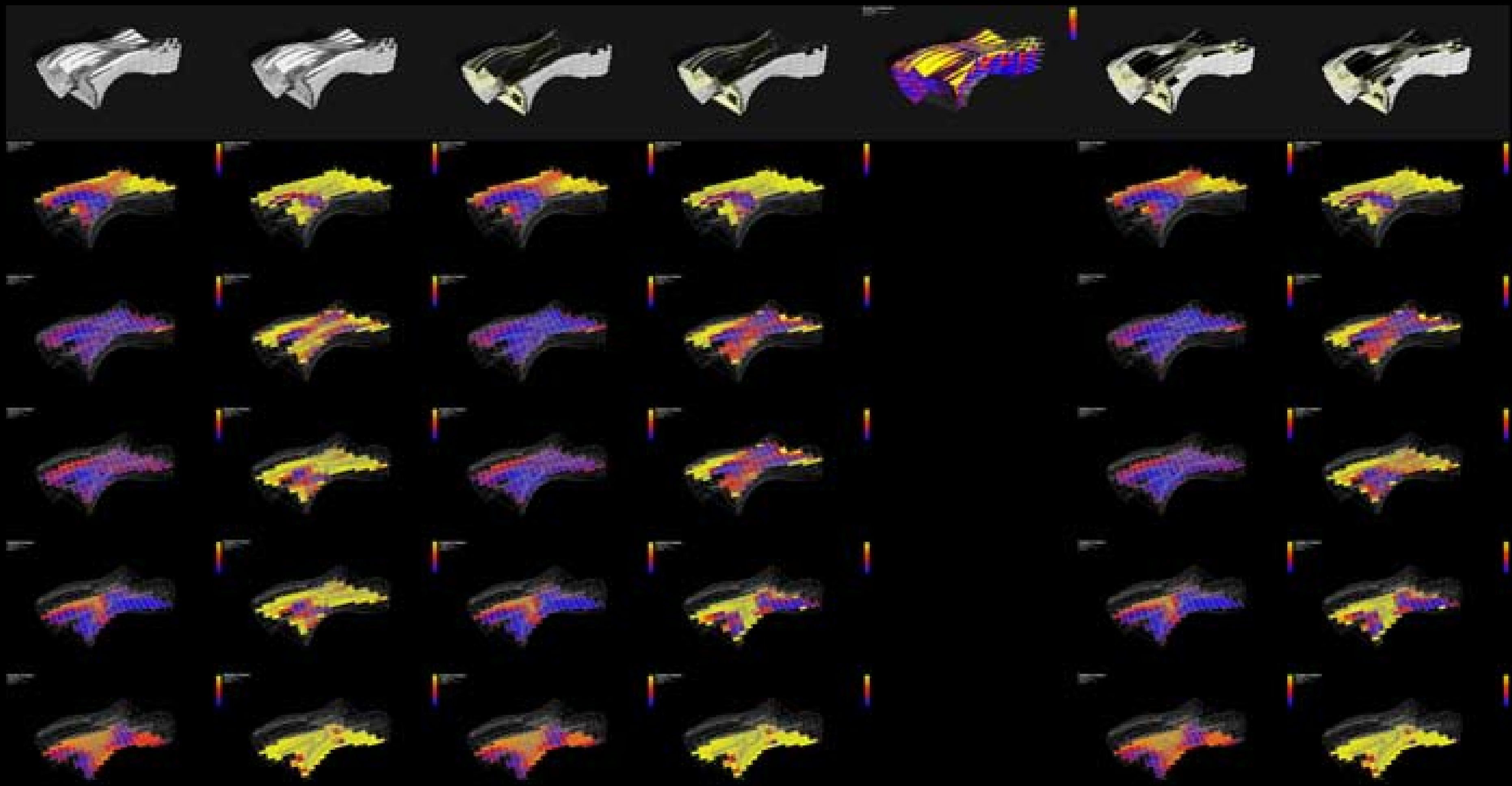
daylight performance simulation
1st june 12.00h

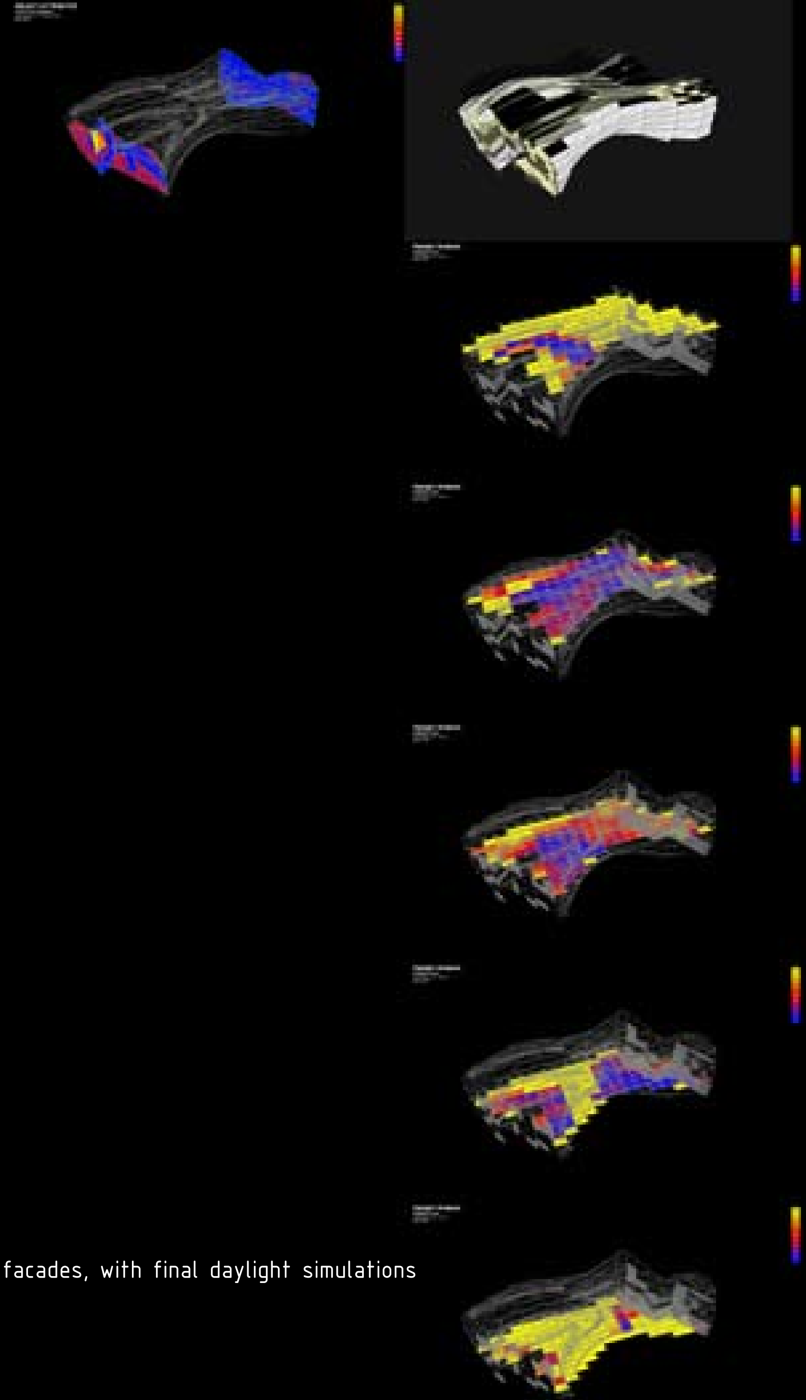


3. Daylight simulation of Design II paneling organization and new parametric organization.



4. Daylight study of Design III with colour properties

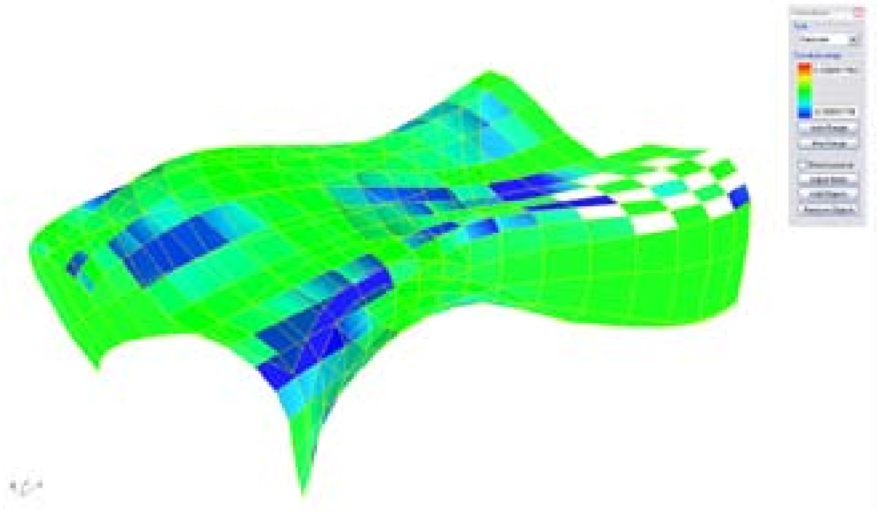


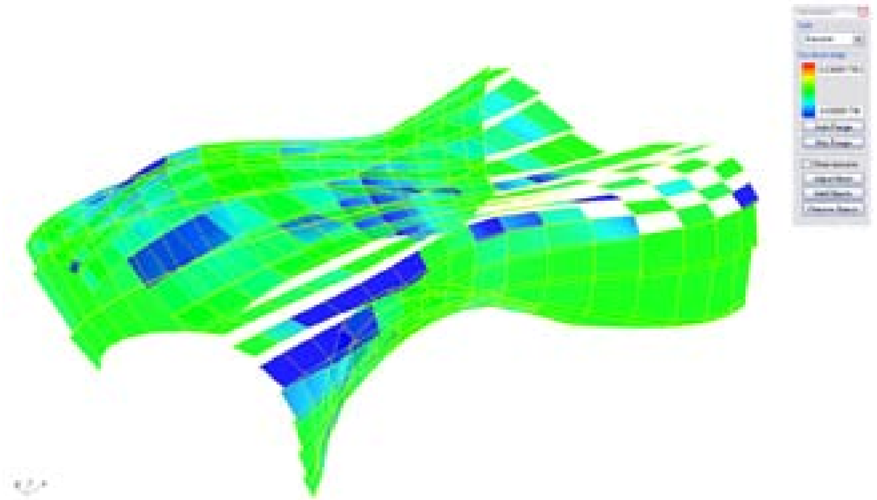


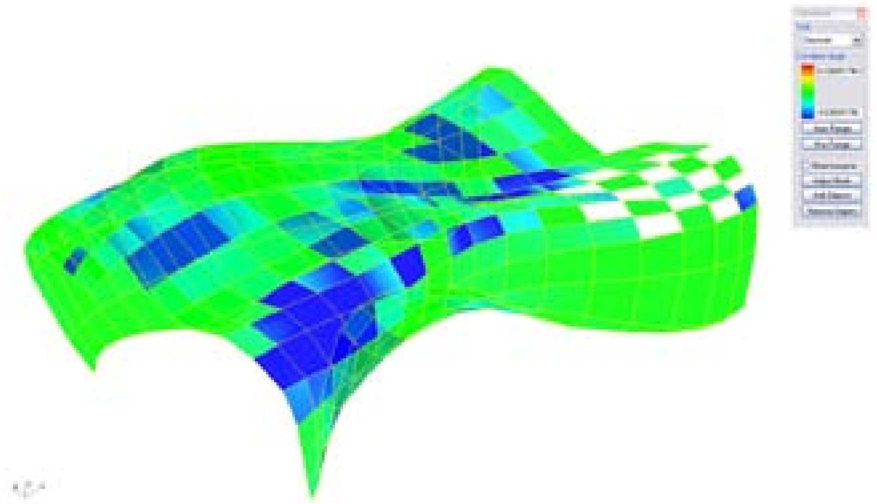
5. Cumulative simulation of East and West facades, with final daylight simulations

9.5 DIGITAL TO PHYSICAL

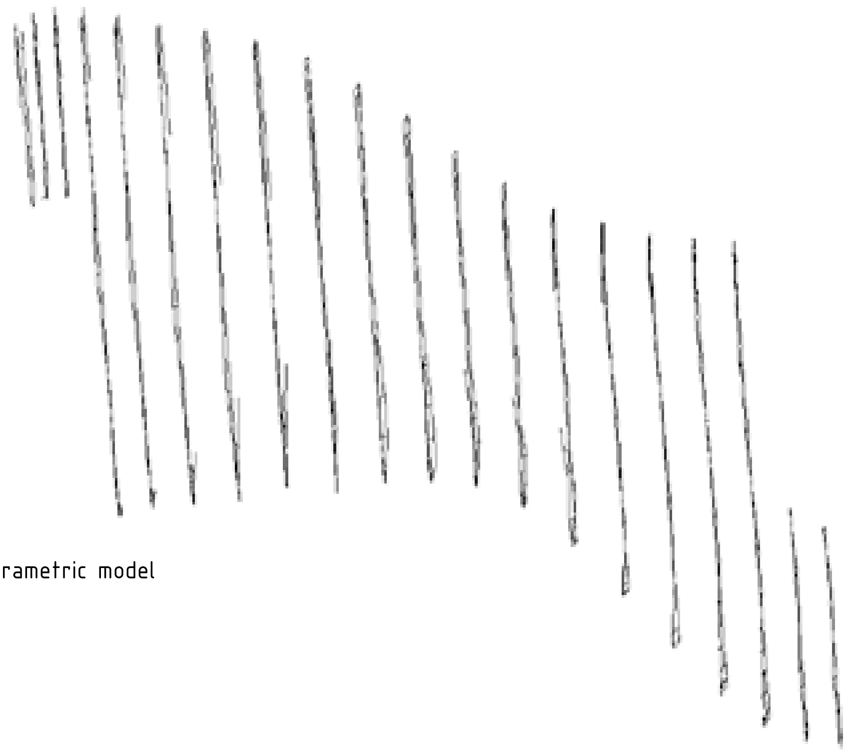
Gaussian analysis performed to test panel curvature, which can give indications of production costs according to complexity of the analysed geometries.



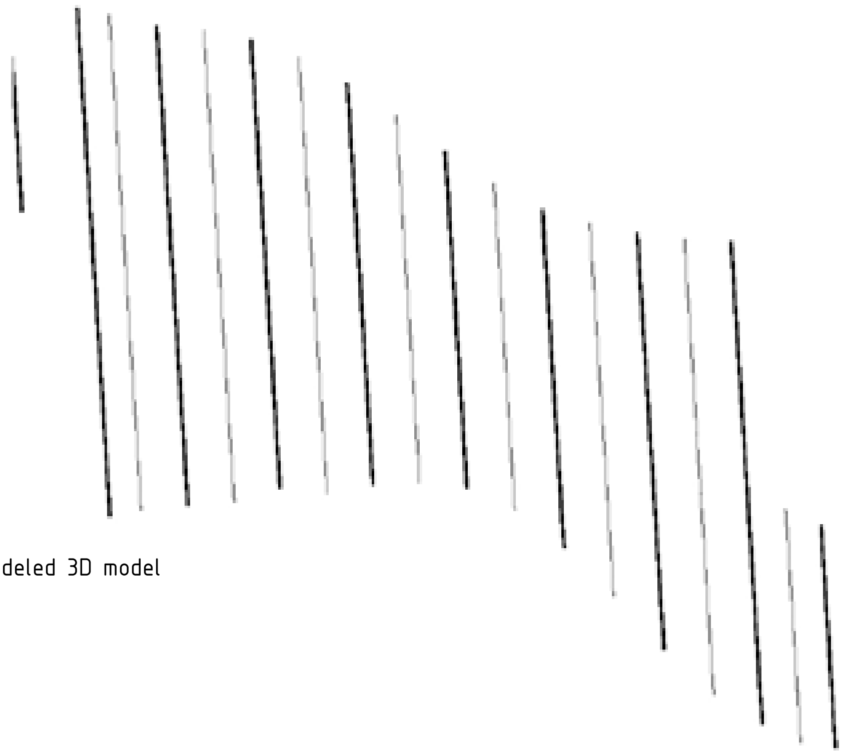




The parametric model is remodeled with straight geometries, ensuring better force flow and improved manufacturing potentials.



Parametric model



Remodeled 3D model

9.6 PHYSICAL MODELLING OF COMPONENTS

Models are created to test structural entegrity, reflection of light and material properties derived through combining wood with a membrane material.