

Delft University of Technology
Faculty of Architecture and the Built Environment
MSc Architecture, AR2A011 Architectural History Thesis



Switching the Parametric Design Approach

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14-04-2021

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Abstract: This thesis examines in what way designers should reassure that the use of parametric design can be switched from esthetical purposes to problem-solving purposes for future global challenges throughout Zaha Hadid Architects' historical approaches and developments. In order to find the answer to the research question, it is important to know how parametric design has been approached in the past, especially from Zaha Hadid Architects' perspective. Thereafter, to find out in what way parametric design has developed over the years. At last, to know how parametric design could be used for environmental and societal matters by proposing new guidelines for the usage of parametric design. This research shows that in order to reassure those ambitions, it is important to change the parametric design intent into a more environmental and society focused process to get a more sustainable and social parametric design result.

Key words: Parametric, Design, Architecture, History, Zaha Hadid, Sustainable, Climate change

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Chapter 1 Preface

When you think about contemporary architecture, you think about architecture that tries to go beyond the boundaries of what the human mind is capable to visualize. For example, the Heydar Aliyev Centre by Zaha Hadid, the Metropol Parasole by Jürgen Mayer-Hermann or the Walt Disney Concert Hall by Frank Gehry. How do architects nowadays even design these beautiful and complex-shaped compositions into a functional building? The answer is simple, they use Parametric Design as a tool to get their composition into realization. However, parametric design can be used for many more purposes than designing a structure which is aesthetically pleasing to look at. It can also be used as a problem-solving tool.

Since design projects are expected to be more complex in the future, with responsibilities towards future global challenges, it is important that the architect of the future uses parametric design as a tool for complex problems like climate change and urbanization. The issue, however, is the question whether the intention to use parametric design are beneficial for the built environment, since the intention to use it varies. That's why Parametric design has been criticized whether it will be the future or not. Obviously Parametric design needs a comeback and leading architectural firms and figures already have been pleading for it. That's why it is important to find out what kind of impact parametric design has made throughout specific perspectives from the past, find out why parametric design has switched from an esthetical approach to a problem-solving approach and to propose new guidelines for the intention to use parametric design.

Also, since it is a short history, has been done by many architects/ architectural offices and it is being applied in all sorts of types of buildings, it is responsible to make the short history explicit from an influential architect's or architectural firm's point of view while also looking at a specific building to briefly determine their vision and approaches towards parametric design. Zaha Hadid Architects has been chosen since they have a big impact on the field of parametric design throughout their existence. Taking all these aspects into consideration, the research will be guided by the following research question:

In what way should designers reassure that the use of parametric design can be switched from aesthetical purposes to problem-solving purposes for future global challenges throughout Zaha Hadid Architects' historical approaches and developments?

In order to find the answer to the research question, it is important to know how parametric design has been approached in the past, especially from Zaha Hadid Architects' perspective. Thereafter, to find out in what way parametric design has developed over the years. At last, to know how parametric design could be used for environmental and societal matters by proposing new guidelines for the usage of parametric design. The primary source for this research will be Zaha Hadid Architects: evolution book, since the practice's remarkable journey from analogue to digital methods is outlined which contains materials to analyse ZHA's contribution to parametric design. Furthermore, I will use Patrick Schumacher's academic journal articles about parametricism and parametricism 2.0 as secondary sources. Since he was a long-life friend of the founder and starchitect Zaha Hadid and currently the owner of Zaha Hadid Architects, his perspective on parametric design represents the firm's intentions and approaches.

Chapter 2 An Introduction to Parametric Design

Before we dive deep into this research regarding parametric design, it is important to be able to understand the definition of parametric design. Also, by comparing this topic to other design methods, the difference between parametric and non-parametric can be clarified better. Thereafter a short and brief history of parametric design will be discussed in this chapter to fully understand it's background.

Parametric design is a form of computational design and can be practiced in programmes such as Robert McNeel & Associates' Grasshopper, and Revit Autodesk's Dynamo. According to the website of the Master in Collective Housing, parametric design establishes a system of parameters, variables and restrictions to create an object by changing those variables that define the system by means of algorithms (Master in Collective Housing, 2021). In other words, you have full control of the dimensions of an object by changing variables that define the shape of that object. If you take a cube for example, you can make changes of the location by moving it side to side, back and forth and up and down. Also, you can change the length of the sides to manipulate the shape of the object. This concept is represented in figure 1. Theoretically you can do this to every object. By using this concept, you can generate complex geometries.

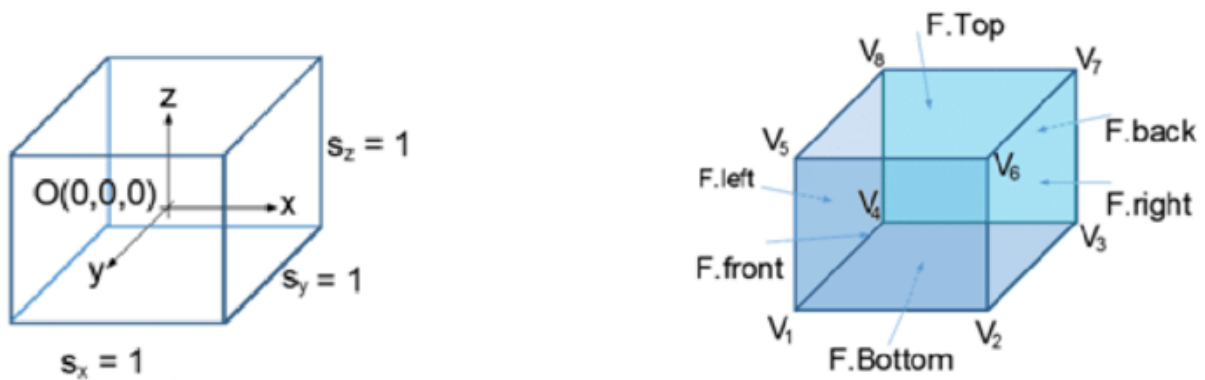


Figure 1: Parametric representation of a cube (Khoshelmam et al., 2018)

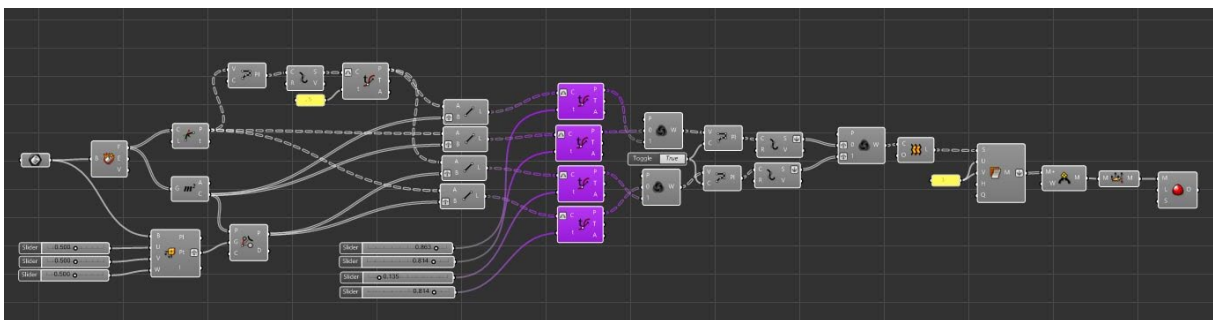


Figure 2: Example of a flowchart script (Food4Rhino, n.d.)

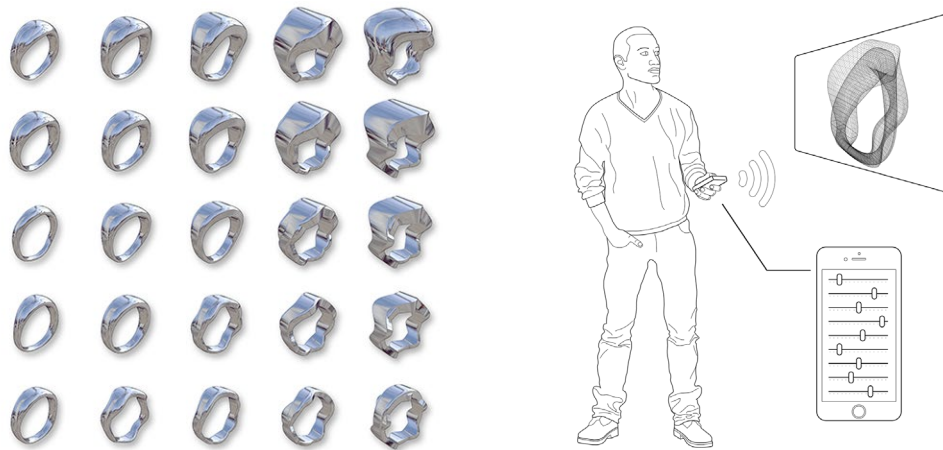


Figure 3: Computer renderings of ring shapes generated using the parametric jewellery design and fabrication system. (Fischer & Christiane, 2015)

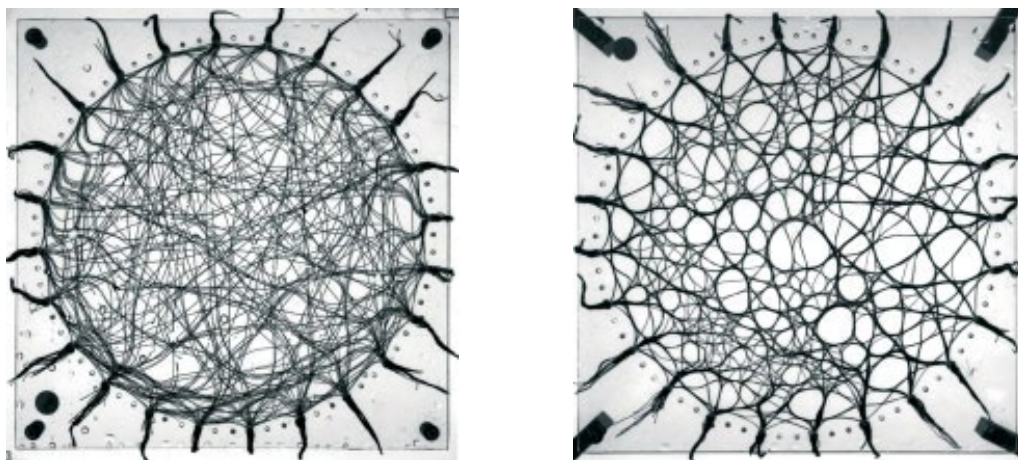


Figure 4: Wool-thread model to compute optimised detour path networks. (Kolodziejczyk, 1991, as cited in Schumacher, 2009)

The most important feature about parametric design is that the parameters that define an object are user-defined. In other words, users set the condition of a certain operation. The designer's intentions are represented in the flowchart script using object-shaping tools, and the design response is the outcome of that (see Figure 2). The script with object shaping tools itself is not the only thing that defines the shape of the object. Also, the parameters generate the shape of the object. Parameters are in this context the numeric values that define the length, width, height, location, and direction of an object. These parameters are variable and can be changed by just setting a different value or use sliders to test different kinds of design responses much more quickly. As seen in figure 3, you can manipulate the geometric shape of an object, in this case a ring, using (user-defined) parameters.

Also, a good thing to take in mind is that parametric design is not an architecture style itself. It is rather a tool that helps the designer to define a shape using algorithms. When you refer to "parametric architecture" you actually refer to a building which was generated with the help of parametric design rather than an architecture style itself. Looking back at Figure 3, you can see that the shape of all the different rings can not necessarily be defined as a certain style since the parameters shape the ring into different aesthetics rather than maintaining a certain aesthetic. Therefore, as Sir Frazer said:

"The use of parametrics as such does not necessarily lead to any style at all, and is just an efficient way of flexibly describing geometry" (Frazer, 2016, p.21).

For now, we only discussed the characteristic of parametric design that it helps to define a shape, but it can be used for so many more purposes. Looking at Figure 4, This image shows the effect of using parametric design in order to compute a solution that reduces the total length while maintaining a minimal detour factor (Schumacher, 2009). The key aspect that this example shows is to create an optimized solution for complex problems with the help of manipulative computational methods. This is why parametric design can be a useful tool to tackle complex (design) problems which can't be comprehended immediately and as efficient without the help of computational methods.

Up to this point we covered most aspects regarding the definition and characteristics of Parametric design. The difference however between parametric and non-parametric can still be confusing. To understand its differences, you should consider parametric design as a type of computational design or modelling. Computational modelling is considered as a design tool or method, like traditional methods such as drawing and scale modelling. According to Sir Frazer, computer modelling is a method of virtual representation which allows ideas to be developed, described, visualized and evaluated without the expense of actual construction or the time-consuming task of producing drawings (Frazer, 1995). An important feature in Frazer's definition is that computational methods actually save time and are more efficient than traditional design methods. Like Kilkelly said in his article, designers traditionally rely on intuition and experience to solve design problems while computational design aims to enhance that process (Kilkelly, 2017). The difference between parametric design and other types of computational design however is that computational design generally allows the user to shape objects using tools provided by the software while parametric design enhances this concept by using a set of interchangeable parameters which automatically change the result.

"Parametric design affects the traditional way of developing architectural or urban planning projects. A few years ago, projects were executed as something rigid, where data was introduced to achieve a goal without much flexibility. With parametric architecture, projects have become a process where it is possible to modify variables and constraints almost instantaneously, resulting in a flexible and adaptable design." (Master in Collective Housing, 2021)

Parametric design can be interpreted from this citation from the Master in Collective Housing website as a contributing factor on top of traditional methods which provides flexibility and adaptivity to the design process.

If we look at the word "parametric" you can subtract 2 words: Para and Metric. According to the definition of RxList, Para- has its origin from Greek and means beside, or beyond (Stöppler, 2021). Combine it together and you get a phrase which means beyond measures. Interpreting this phrase might help you to understand the background of parametric better. Parametric design has its origin in mathematics. According to Daniel Davis one of the first times parametric is being used, even before the invention of the computer, was in James Dana's 1837 paper *On the Drawing of Figures of Crystals* (Figure 5) where he explains the general steps for drawing a range of crystals and provisions for variations using language laced with parameters, variables, and ratios (Davis, 2019).

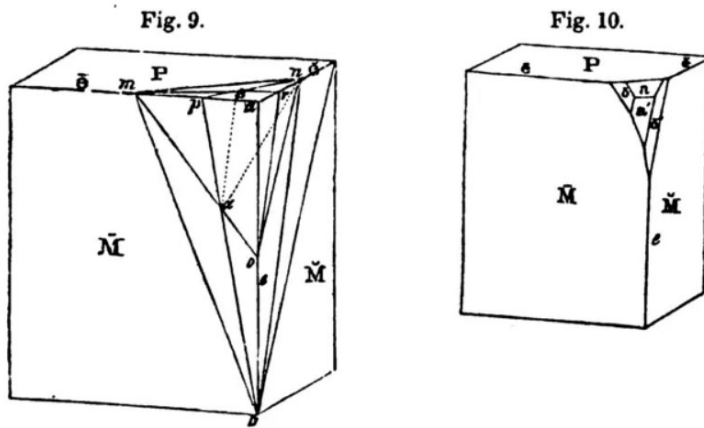


Figure 5: Instances of James Dana's crystal drawings showing the impact of changing the edge chamfer ratio (Dana, 1837 as cited in Davis, 2019)

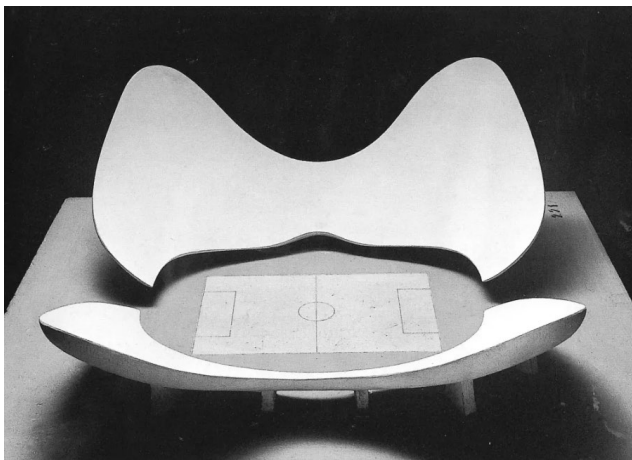


Figure 6: Model of the stadium by Moretti (Bucci and Mulazzani, 2000, p.114 as cited in Davis, 2019)

Many years Later Antoni Gaudí would use parametric in a more analogue way of doing instead of digital which would later be invented. According to Davis, Gaudí first began designing architecture with parametric catenary curves and parametric hyperbolic paraboloids at the end of the nineteenth century using analogue models underpinned by parametric equations (Davis, 2019). With the invention of the computer, the 60s and the 70s were a booming period for the introduction of computational design methods. One of the first pioneers in the start of the computer age regarding parametric design was Luigi Moretti. Moretti was one of the first who described parametric architecture, which he defines as the study of architecture systems with the goal of “defining the relationships between the dimensions dependent upon the various parameters” using the design of a stadium (Figure 6) to explain how it's form can derive from parameters (Moretti, 1971 as cited in Davis, 2019).

In conclusion parametric design establishes a system of parameters, variables and restrictions to create an object by changing those variables that define the system by means of algorithms. It has its origins in mathematics, and it distinguishes itself as a computational design method which in contrast to traditional design methods are more efficient in terms of time saving and visualising. Also, it provides flexibility and adaptivity to the design process on top of traditional design methods. The use of parametric design enables the capability to make complex geometries and optimizable solutions for complex design problems.

Chapter 3 Zaha Hadid Architects' Approach to Parametric Design

In this chapter, the question how parametric design was approached in the past from Zaha Hadid Architects' perspective will be briefly discussed. In order to find out how they approached parametric design, a short and brief summary of their vision will be made explicit. This is important in order to find the connection between their vision and the execution of their vision within the case study in contrast to parametric design. Thereafter the background of Zaha Hadid architects' way of designing in the early years, even before the implementation of digital methods, will be made explicit. Afterwards, the question how the office benefited from switching from traditional to digital design methods including parametric design will be discussed in contrast to their vision. At last, a case study of Zaha Hadid Architects will be analysed in terms of the concept, interaction with parametric design and the connection between their vision. The case study for this chapter is the Phaeno Science Centre in Wolfsburg, Germany.

Zaha Hadid Architects is an architectural firm, founded by Zaha Hadid, who have been one of the major architectural firms in contemporary architecture and architectural innovations like parametric design and Building Information Modelling. They have inspired millions of people by their complex structures and architectural composition. According to their website where they briefly discuss their position, form and space are integrated within the structure of buildings that evolve from their surroundings and tie programmes together to seamlessly combine them for formal strategy and spatial experience. They want to engage the city as an act of attraction rather than imposition and in order to achieve this goal, they make sure that their works are each unique to its context, culture, function and innovation (Zaha Hadid Architects, n.d.-a). In other words, Zaha Hadid uses innovations to achieve a unique design through integral solutions covering all architectural disciplines. They especially use parametric design into their design process, providing integral solutions for every discipline. According to Peter Cook adaptive variation, continuous differentiation and parametric figuration covers every connected discipline from urbanism level to the level of building details (Cook, 2004 as cited in Lee, 2015). In order to make sure that each building is unique to its context, function and innovation, Zaha Hadid Architects make use of digital methods such as parametric design and Building Information Modelling to provide integral and adaptive solutions for every discipline.

Zaha Hadid Architect's remarkable compositions, complex geometries and controversial architecture were established by the founder and prize winner Zaha Hadid herself. According to AbdUllah et al., her designs were characterized by Abstraction and Fragmentation, defying gravity, relationship between the building's context, layering, play of light and fluidity/ seamlessness (AbdUllah et al., 2013). Zaha Hadid can be considered as a true visionary because of her deconstructivist architectural style, which was at the time of her early career beyond imaginable to be implemented in architecture, let alone feasible to be constructed into reality. That's why according to SAO Architects Blog, she became a paper architect because her designs were very controversial to be actually realized and constructed at site until later on into her career (SAO Architects, n.d.). She was more famous in that time because of her impressive architectural paintings in suprematism style. You could even argue that her paintings and eventually her architecture style were inspired by Malevich's paintings. According to Lee's article about Zaha Hadid's Design Genealogy, the link between Hadid and Malevich started with her 1976-77 graduation thesis for the Architectural Association, Malevich's Tecktonik (Lee, 2015).

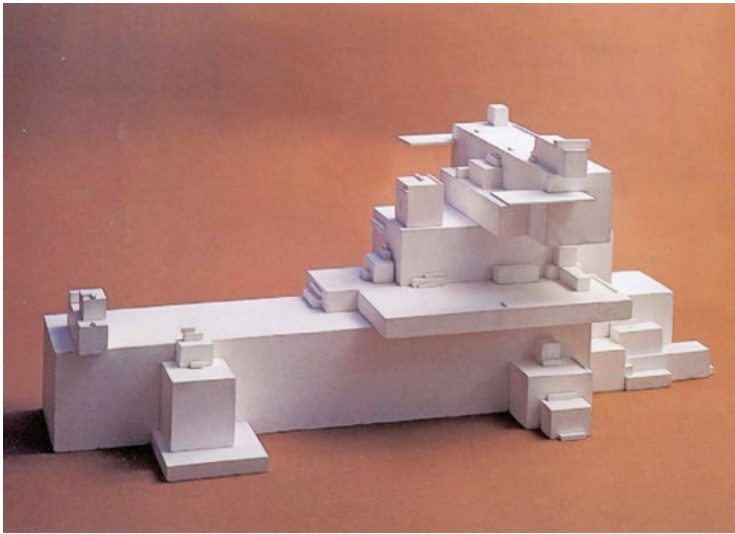


Figure 7, left: *Alpha Architecton* by Kazimir Malevich (1920 as cited in Lee, 2015)

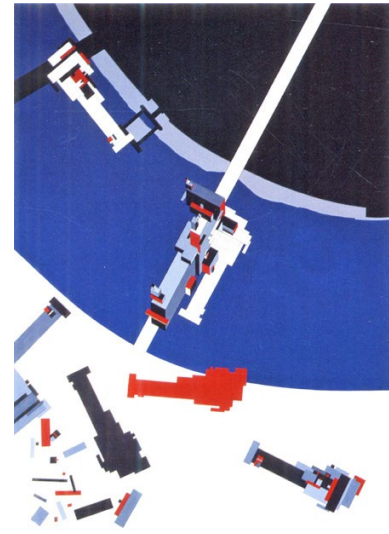


Figure 8, right: *Malevich's Tecktonik* by Zaha Hadid (1976 as cited in Lee, 2015)

Within Figure 7 and 8, you can see how Zaha Hadid translated Malevich's composition into partial elements that define a 3-dimensional design into an architectural language. This is emphasized by the partial elements such as a conceptual 3D view and multiple floorplans. Zaha Hadid's paintings, created during her early career actually reflected the style of Malevich's paintings into a more 3-dimensional composition for conceptual representations. According to Lee, Hadid portrayed architecture via simplified forms, treating background or landscape and buildings in much the same way as Malevich's work regarding shape and color in a cubo-futuristic style (Lee, 2015).



Figure 9, left: *Morning in the Village after Snowstorm* by Kazimir Malevich (1913 as cited in Lee, 2015)

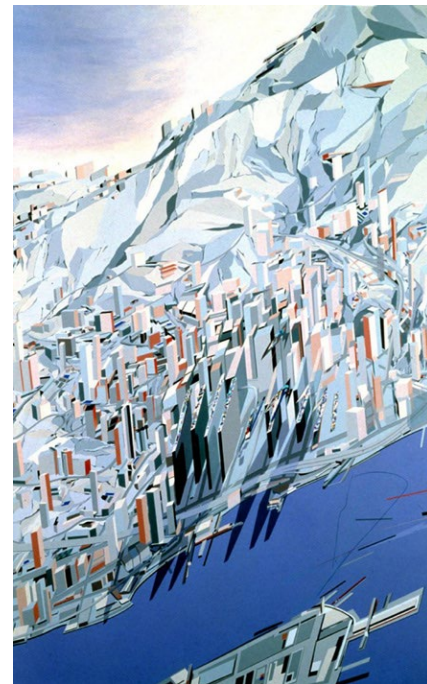


Figure 10, right: *The Peak Leisure Club* by Zaha Hadid (1982 as cited in Lee, 2015)

Within Figure 9 and 10 you can clearly spot the similarities. The usage of colour is similar to each-other since both paintings use red and blue to highlight depth. Furthermore, the usage of cubic and triangular shapes to highlight elements in both works are major similarities. At last, you can see that Zaha Hadid has implemented her own style in inspiration from Malevich since her paintings have a more 3-dimensional composition, clearer depth and the use of shadows to highlight 3D objects while Malevich's painting has a more 2D composition.

Through her paintings you can clearly recognize that the inspiration of designing complex structures is inspired from cubism, suprematism and deconstructivism within art. These kinds of compositions were hard to realize especially during her early career as concerned earlier. That is the case since the use of traditional methods such as drawing, scale modelling, constructional feasibility through calculations and functional studies were especially in that time hard to develop. With the innovations regarding digital design methods, the realization of her complex projects were more feasible than before. Her design process and methods enabled the use of digital methods and were according to the diagram in Figure 11 from AbdUllah et al. especially based on data collection, research and finding relations between variables (AbdUllah et al., 2013). And that is where parametric design finds its purpose in Zaha Hadid's designs. Since it is a method to solve complex problems and to practice advanced form-finding, converting the collected data is much more convenient to find relations between elements through parametric models. This applies to the vision of Zaha Hadid Architects since they want to achieve a unique translation of environmental, societal and functional matters and finding relationships between data unique to the building's context is the perfect way to find integral solutions for that building. In conclusion, parametric design benefits ZHA's design approach.

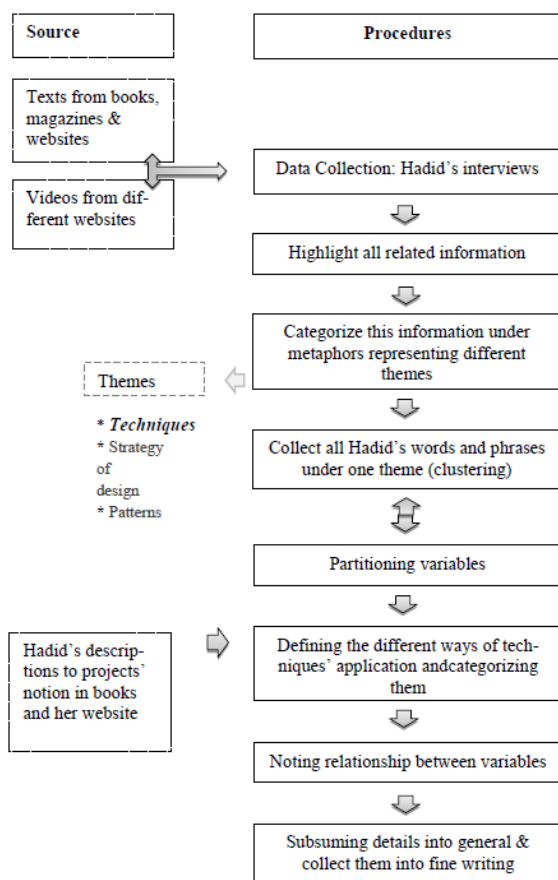


Figure 11: Content analysis for Zaha Hadid's interviews (AbdUllah et al., 2013)

Up until this section the vision of Zaha Hadid Architects, the design methods of Zaha Hadid and the benefits of parametric architecture for Zaha Hadid Architects has been discussed. In order to truly recognize their approach towards using parametric design and the relationship between the project and their vision, it is important to analyse a case study which truly represents these aspects from its concept. In this case the Phaeno Design Centre in Wolfsburg, Germany has been chosen since it is considered to be one of the first projects from Zaha Hadid which utilises parametric design methods.



Figure 12: Phaeno Science Centre (Huthmacher, n.d.)

The Phaeno Science Centre, completed in 2005 by Zaha Hadid Architects, is a radical design where parametric design is being applied to realise this project structurally, contextually and functionally. According to the book *Zaha Hadid Major and Recent Works*, the project is based on an unusual volumetric structural logic to create a crater landscape by structural cones turned upside down (Hadid et al., 2004b). As you can see in Figure 12, the composition of the building is rather seamless and defies gravity from the inside out.

From the elevations and section in Figure 13, you can notice that the structural complexity, the functional layout and the design of the façade blends perfectly into each other, creating an architectural masterpiece from which the section can be considered as a piece of art due to its creation of unique spaces.

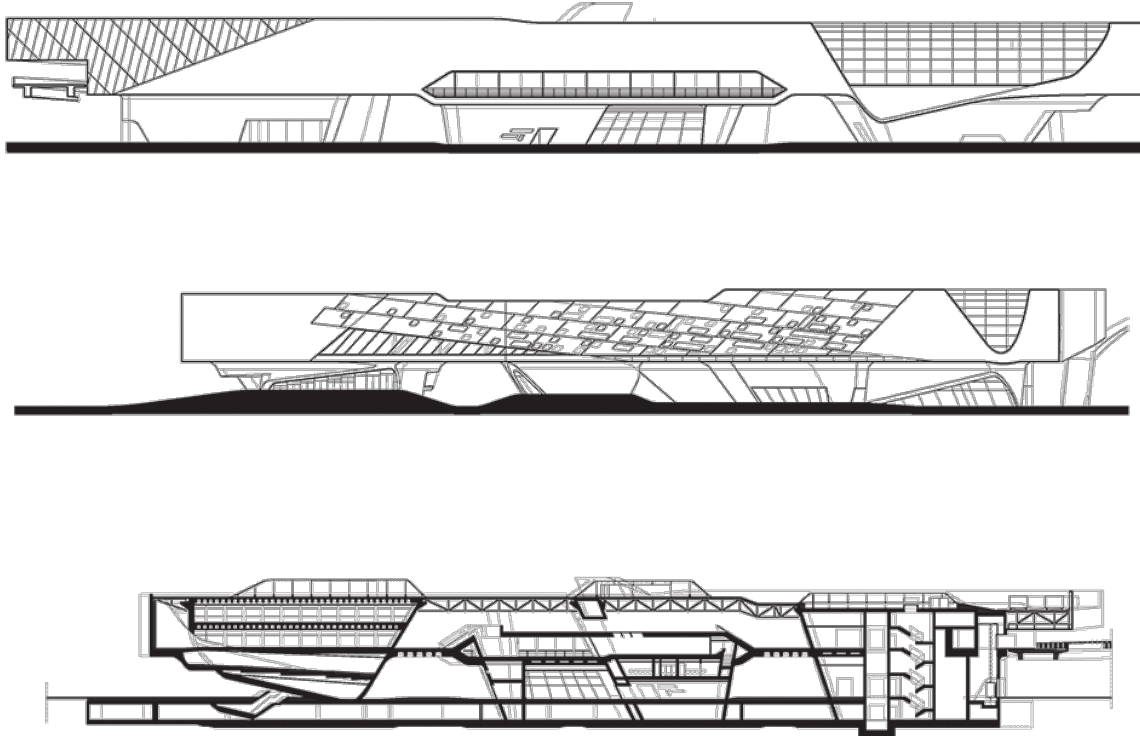


Figure 13: North Elevation <top>, South Elevation <middle> and Main Section <bottom> (Zaha Hadid Architects, 2005)

Looking at Figure 14, The interior is composed of an open space layout, where the structural cones also serve as functional spaces and access points. The website page from the EU Mies Award covering the Phaeno Science Centre gives a brief and accurate summary of the environment that the interior creates:

“The building is structured to maintain a considerable degree of transparency and porosity on the ground, since the main volume of the exhibition-scape is raised, covering an outdoor public plaza with commercial and cultural functions residing in the structural concrete cones. An artificial crater-like landscape is developed inside the open exhibition space, while protruding volumes accommodate other functions of the centre.” (EU Mies Award, n.d.)

This building emphasizes cultural value, creates big public spaces and divides the programme with within clusters, which all contributes to a healthy research environment.

To Achieve all these conceptual goals, they used parametric design methods for the first time, according to architectuul’s webpage about this building, by utilizing digital animation for the spatial programme of the building. This concept can be seen from Figure 15. This is considered as a predecessor of parametric design since it parametrically engages with form and function (Architectuul, n.d.).

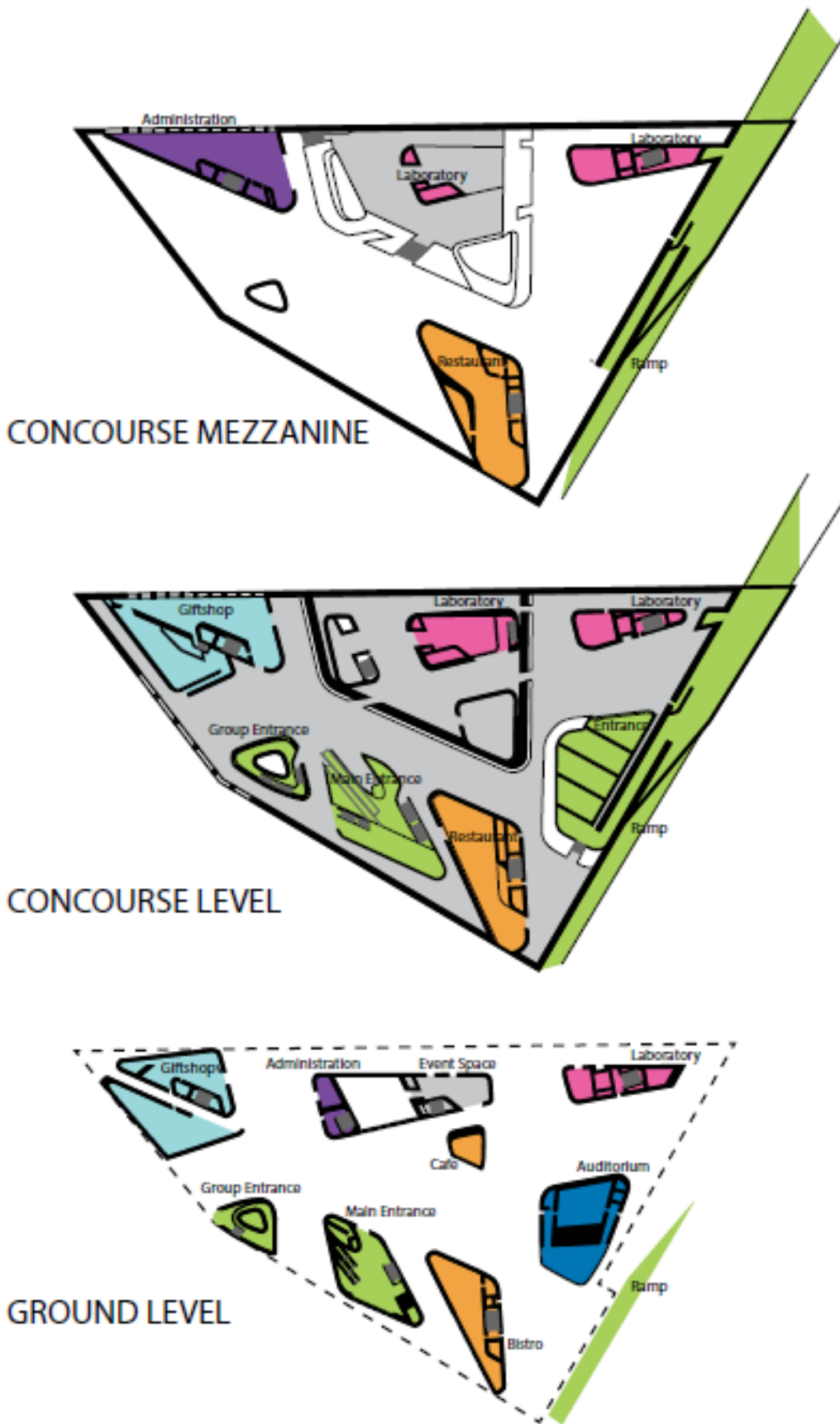


Figure 14: Floorplans in contrast to the functional layout (Mistur, 2006)

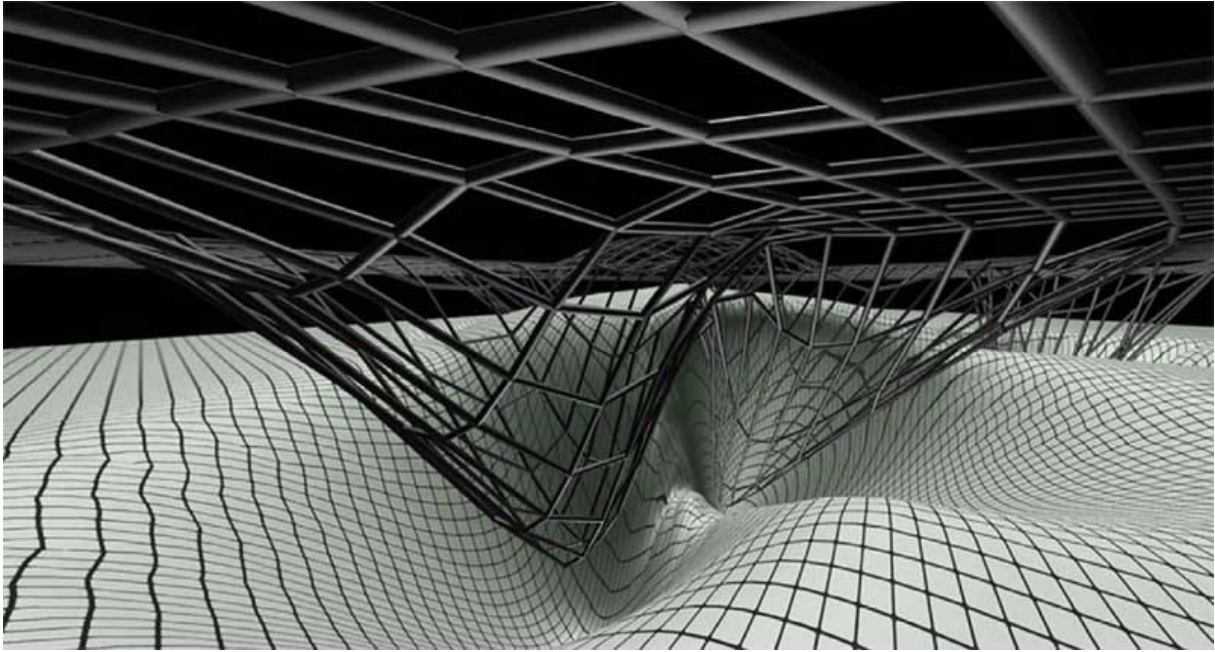


Figure 15: Phaeno Science Centre parametric formfinding (Hadid et al., 2004b)

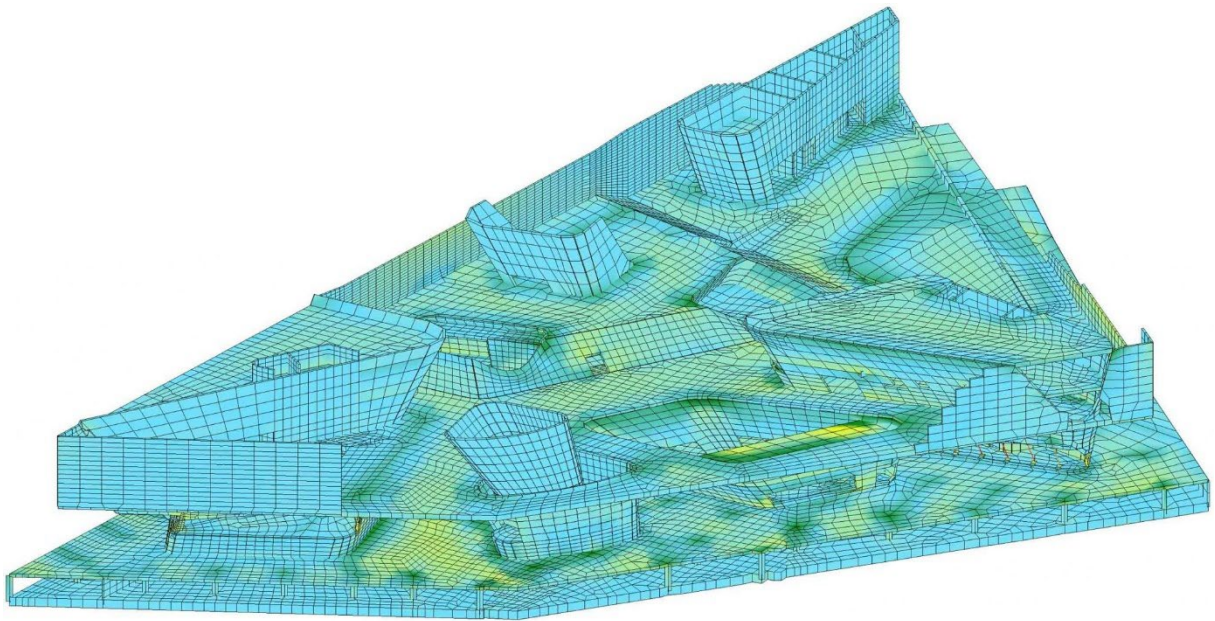


Figure 16: Complex analysis model (Zaha Hadid Architects, n.d.-b)

They have also been using digital design methods to calculate the structural stress of the building. Since the building has a complex shape, digital methods such as the complex analysis model from Figure 16 to get a better understanding about the division between the structural loads.

With the use of parametric design, Zaha Hadid Architects have achieved to integrate multi-disciplinary systems into a unique contextual building with complex geometries. Through spatial, contextual and structural interventions in contrast to materialisation, this building sets the pace for an avant-garde way of designing buildings through digital design methods such as parametric design. This way of designing is in contrast with their vision as discussed earlier in this chapter.

The answer to the question how parametric architecture was approached in the past from Zaha Hadid Architects perspective all start with the visionary Zaha Hadid. She laid the foundation of implementing suprematism, deconstructivism, and cubo-futuristic style, inspired from Malevich's paintings and adapted this in a more 3-dimensional way of thinking and designing. This architectural style, in combination with the vision to achieve an integral design unique to its urban fabric and composition, asks for the need of digital design methods such as parametric design. Within her design method, the firm collects data through extensive research and through digital design methods such as parametric design, relations between elements are used to achieve an integral solution for complex design problems. This concept is well reflected in the Phaeno Science Centre, since the spatial, contextual and structural interventions in contrast to materialisation blends well in an integral design providing public spaces, functional efficiency, cultural value and a healthy research environment. This was realized for the first time with the help of parametric design methods and sets the pace for their future as one of the leading firms in parametric design.

Chapter 4 The Development of Parametric Design

In this chapter, the question in what way parametric design has developed over the years will be briefly discussed. In order to find the answer to this question it is important to know how parametric design was generally used and defined throughout the years referring to Patrik Schumacher's article: Parametricism. Thereafter, to discuss the critics behind parametricism and address them. Afterwards, the response to the criticism behind Patrik's first article will be addressed referring to his article: Parametricism 2.0. Within this discussion, his vision about how we need to approach parametric design in the coming years will also be addressed. At last, a short and brief analysis of the past will be made explicit by means of a timeline.

In this section, Patrik Schumacher's article, Parametricism, will be discussed to find out how Parametric design has been used, and defined throughout the first stage of its development. Patrik Schumacher (Zaha Hadid's long life partner and currently the CEO of ZHA) explains why parametricism has become the dominant, single style for avant-garde practice today and why it is particularly suited to large-scale projects. This article is also the first time in history that parametric design was addressed as a new architectural trend.

According to Schumacher, Parametric design has rooted from the mid-1990s and only fully emerged in its recent years. He addressed that parametric design succeeds Modernism as the next step in systematic innovation within architecture, which automatically means the end to the transitional phase of uncertainty from Modernism. He also argues that it is the task of architecture and urbanism to solve complex problems, and this societal demand can be addressed by the use of parametric design techniques. Interestingly enough, he defines parametricism as a new style in avant-garde architecture and urbanism since the techniques in question inspired a movement with new ambitions and values (Schumacher, 2009, p.15). According to this logic, Parametricism is the successor of modernism achieving new ambitions towards a digital-driven and complex society. As he said in his article:

"The current stage of development within parametricism is as much to do with the continuous advancement of the attendant computational design processes as it is due to the designer's grasp of the unique formal and organisational opportunities afforded by these processes. Parametricism can only exist via the continuous advancement and sophisticated appropriation of computational geometry." (Schumacher, 2009, p.17)

Parametric design, according to this citation, adds value to the design process due to its opportunities in efficiency. He even predicts that parametric design is becoming so important that it is no longer possible to compete with avant-garde architectural firms if you do not master parametric design. For this fact, he seeks to formulate the most important ambitions towards parametric design to spread awareness:

1. Parametric interarticulation of subsystems
2. Parametric accentuation
3. Parametric figuration
4. Parametric responsiveness
5. Parametric urbanism

For parametric interarticulation, the goal is to change from single system components to multiple scripted subsystems that correlate with each other. For example, a façade with multiple components

can be scripted in a way that every piece is integrated into one adaptive system of elements. For parametric accentuation, the goal is to enhance the overall sense of architectural experience by means by integration of organic form-finding. For parametric figuration, the goal is to create parametric variation by means of testing multiple variables/ parameters. For parametric responsiveness the goal is to find relationships between use patterns so the model can adapt in response to an adaptive environment. For parametric urbanism, the goal is to integrate every intersecting discipline from the built environment within a system to find relationships between them (Schumacher, 2009, p.17).

From this article you can notice that Schumacher discussed many ambitions regarding parametric design and that it is basically the future of design. Within his formulated ambitions, designing a better built environment throughout a data-driven approach is the main focus issued in this article. But, in what way has parametric design even proven to make the built environment a better place in contrast to other ways of designing? And how does society benefit from ambitions that contain mostly aesthetic ambitions? That is why it is important to address the critics behind the first stage of parametricism in this section.

Patrik Schumacher in his article often talks about parametricism as an architectural style, but in John Frazer's article he even argues that parametricism doesn't lead to a different style at all and it is just an efficient way of flexibly describing geometry, as argued in the first chapter (Frazer, 2016). Since John Frazer is also one of the leading figures behind computational and parametric design, it is interesting to see their differences within this matter. But, as argued in the first chapter, this research points more towards Frazer's position in this matter.

Zaha Hadid Architects way of design were criticized in the way they approach architecture. A short and brief opinion from Rowen Moore in 2015 addresses all these critics Zaha Hadid Architects received throughout their existence. He argues that Hadid's approach to designing buildings make them more difficult and expensive to build and increases the chance that the building does not work functionally. In other words, the shape comes first, and the rest follows from that. Also, he said that the theory behind Hadid's approach can change the way people live in cities and encourage interactions between them, but the firm tends to build more disconnected monuments instead of a building made for the people (Moore, 2015)

In 2016, Zaha Hadid rejected those claims that her architecture is selfish, and she believed that she was widely misunderstood by the mainstream media. In her defence, cited in Dezeen's article about this matter, architecture is not a medium of expression to her, but rather "that architecture must contribute to society's progress and ultimately to our individual and collective wellbeing." (Zaha Hadid as cited in Fearson, 2016). Zaha Hadid Architects present themselves as a firm that want to contribute to societal matters and by looking at the case study in the previous chapter they achieve to do so, but Moore's points of criticism do actually make sense in the way that making complex structures does not always benefit society. After Hadid passed on March 31, 2016, and shocked the world, the term parametric architecture is again one of the major topics addressed in architecture-based media.

Obviously, after all the criticism towards parametricism it needed a redemption. The term needs to be addressed again and should be formulated again in a sense that implementing parametric design actually benefits society. That's why Patrick Schumacher released his article Parametricism 2.0, which will be addressed in this section. This paper reinterprets the definition behind parametricism and why it should still be used in contemporary architecture. In order to address the critics of Parametricism the author has relaunched a self-critical discussion about this matter.

According to Schumacher, the aim of this paper is to reverse the fading influence of parametric design within architectural practices and schools influenced by the 2008 economic crisis where the criticism comes from. In his defence for the criticism, the mainstream media fails to understand that societal complexity calls for urban and architectural complexity on the basis of innovative principles (Schumacher, 2016). Surprisingly, Zaha Hadid and Patrik Schumacher address the same critics summarized in the article from the guardian.

Patrik Schumacher even argues that Parametric design is the only style, compared to recent developments in architectural design, that uses computational analytics to provide optimal solutions for complex design problems. As he said in his article:

“Parametricism is architecture’s answer to contemporary, computationally empowered civilisation, and is the only architectural style that can take full advantage of the computational revolution that now drives all domains of society.” (Schumacher, 2016, p.10).



Figure 17: Beijing New Airport Terminal Building by Zaha Hadid Architects (Schumacher, 2016)

Figure 17 shows the early rendering of the new airport terminal in Beijing before completion. The capability of parametric design is showcased in large-scale, high-performance infrastructure projects like this airport terminal, where advantages of complex geometries are intersecting with functional and societal needs. As Schumacher said:

“Due to its versatile formal and spatio-organisational repertoire, Parametricism is the only contemporary approach that can adequately address the challenges posed to architecture by the new social dynamics of the Information Age. Accordingly, it is already addressing all major urban building tasks, on all scales, including infrastructure projects such as railway stations and airports.” (Schumacher, 2016, p.10)

Patrick does admit that some works from parametric designers are not presumed to aim at performance, but rather as expressions of art. He adds that artistic and technological creativity must still play a part in the character of parametricism. The artistic intentions should according to him recede and give way to a focus on emphasizing functional principles and societal purposes, as a

serious contender for global best practice should do. It must become more strategic, applied and performance oriented in order to survive (Schumacher, 2016). Parametric design experienced a switch after Patrik Schumacher published his second article on parametricism. With a more societal and environmental approach, parametric design is argued to be able to solve complex problems for future generations to come.

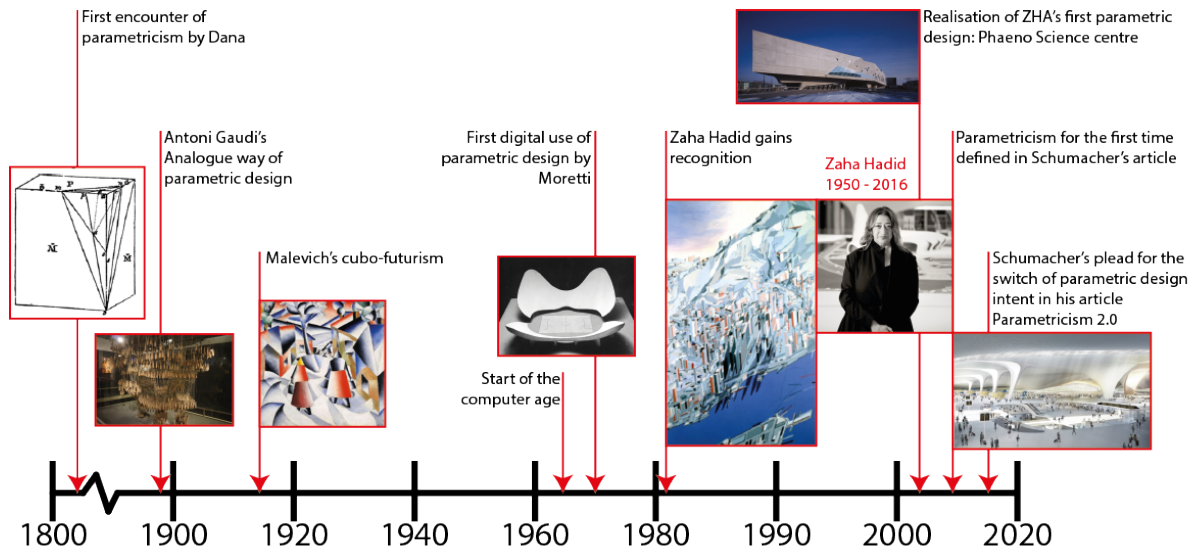


Figure 18: Parametric design timeline (by author, 2022)

The answer to the question how parametric architecture was developed can be summarized by looking at Figure 18. If we look back again at the development of parametric design, it has experienced many shifts in relevancy, feasibility, design approach and ambitions. You can also see that the biggest developments happened from the start of the computer age and is still in development to this day. The moment parametric design was being recognized by the world was initiated from pioneer Patrik Schumacher in his article about parametricism. Here he explains why parametricism has become the dominant, single style for avant-garde practice today and why it is particularly suited to large-scale projects. According to this logic, Parametricism is the successor of modernism achieving new ambitions towards a digital-driven and complex society. These ambitions, however, were more focused on aesthetic quality rather than problem-solving techniques. After the decreasing popularity and criticism towards parametricism, parametric design was in desperate need for a redemption. The biggest shift of the parametric design approach is arguably after Schumacher published his second article about parametricism. Here he reinterprets the definition behind parametricism and pleads to give way to a focus on emphasizing functional principles and societal purposes, so the parametric design intent becomes more strategic, applied and performance oriented rather than focusing on expression. The switch is also relatively speaking the point where we are now. So in order to make sure that it remains that way we are also in desperate need for guiding principles.

Chapter 5 The Next Approach for Parametric Design

In this chapter, the question how parametric design could be used for environmental and societal matters will be addressed. In order to find the answer to this question a brief summary and explanation will be given to discuss how we need to contribute to the challenges facing future generations regarding climate change and urbanization. After that will be discussed how parametric design can tackle these problems to develop optimized solutions within recent developments. At last, what behavioural changes are required from Designers in order to reassure that parametric design will be used in a sustainable and social way by means of proposing new guidelines.

From Schumacher’s article parametricism 2.0, he explained how parametric design should change by solving complex design problems for a better future. What I missed in his article was what kind of interventions architects must perform for future global challenges and which parametric tools would help with that. Also, what I missed in this article was a list of specific design ambitions parametric design to achieve this goal, as he did in his first article about parametricism. In this context it is important to also address these features so architects know how they should position toward future global challenges by means of parametric design. That’s why in this chapter we will dive deep into these aspects to clarify Schumacher’s intentions to solidify the parametric switch.

OUTLINE OF A CIRCULAR ECONOMY

PRINCIPLE 1

1

Preserve and enhance natural capital by controlling finite stocks and balancing renewable resource flows
ReSOLVE levers: regenerate, virtualise, exchange



Regenerate Substitute materials Virtualise Restore

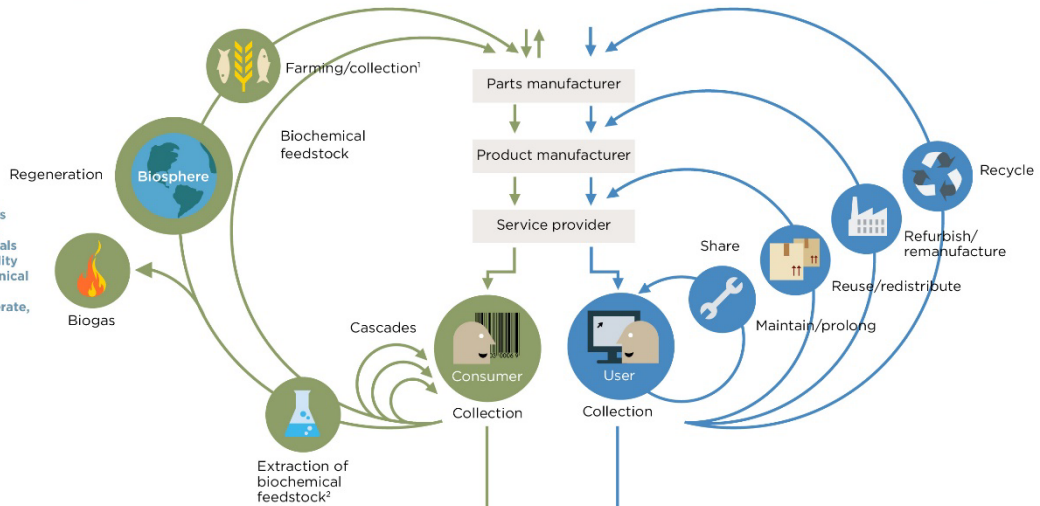
Renewables flow management

Stock management

PRINCIPLE 2

2

Optimise resource yields by circulating products, components and materials in use at the highest utility at all times in both technical and biological cycles
ReSOLVE levers: regenerate, share, optimise, loop



PRINCIPLE 3

3

Foster system effectiveness by revealing and designing out negative externalities
All ReSOLVE levers

Minimise systematic leakage and negative externalities

1. Hunting and fishing
2. Can take both post-harvest and post-consumer waste as an input
Source: Ellen MacArthur Foundation, SUN, and McKinsey Center for Business and Environment; Drawing from Braungart & McDonough, Cradle to Cradle (C2C).

Figure 19: Strategies for a sustainable built environment butterfly diagram (University of Technology Delft, n.d.)

In the current society, problems regarding the built environment are contributing to climate change due to excessive CO₂ emissions and waste of materials. Looking at Figure 19, as cited from the website of the University of Technology Delft and the information received from the Ellen MacArthur Foundation, there are 3 main principles in order to prevent the built environment damaging the climate. The first principle is to preserve and enhance natural materials and energy by controlling finite stocks and balancing resource flows. In the second principle, it is important to optimise resource yields by circulating products, components and materials. And at last, in the third principle the main goal is to minimize systematic leakages and negative externalities (Ellen MacArthur Foundation, n.d.). In other words, if you repurpose a certain material, it is not worth it if the energy it takes to transform the product releases more emissions. For example, steel has a high embodied energy and by heating it up to its melting point a lot of energy is required. So, in order to design for the future without damaging the climate, the designer must be aware of the amount of energy it takes to produce or construct a building and should focus more on preserving materials in many ways as possible. Parametric design is an excellent tool to combine these complex ambitions into a design that takes these elements into account.

In order to achieve a sustainable and socially healthy built environment for the future, the designer should focus on two ways of designing during a design process: Environment Based design and Society Based design. In Zeng's paper about Environment Based Design, he argues that design is driven by a need or an inspiration from the existing environment and in that way should start from the environment, serve the environment and changing the environment (Zeng, 2015). By implementing this way of designing into the designer's design process, they become more aware of the effect their design choices have on the environment. In Zeng's view, the fundamental concept in EBD is that function, form, programme, interventions, solutions, knowledge etc. are all present within its design process (Zeng, 2015), which makes this a suitable combination for implementing parametric design as a tool to achieve integral solutions for complex environmental design problems.

Society Based Design also goes hand in hand with sustainable ambitions towards the future. According to Gardoni and Murphy's paper about Society Based Design, Natural disasters, which become more frequent in the future, enhance social differences. By developing strategies, implementing urban planning and analysing capability of sustainability and resilience, a groundwork for the future is being laid (Gardoni & Murphy, 2018). This is also coherent to work with a parametric design approach since the data coming from analysing capabilities of sustainability and resilience can be translated into a 3-dimensional composition that cover all the strategies needed within urban planning.

With parametric architecture being known for advanced form-finding, it is also a great platform to analyse data in a more 3-dimensional way. This gives the designer a better understanding in how the forces of nature and society work in complex forms and how to find relations between elements to achieve an integral design. An excellent example of a parametric tool that does this in an environment-based way is the LadyBug tool within Rhino's parametric software: Grasshopper. Looking at Figure 20, this tool allows you to do a real-time solar study analysis by using geographical data and sliders to control the solar impact throughout the year. This gives the designer insight in the amount of solar exposure from every side of the building in a certain moment.

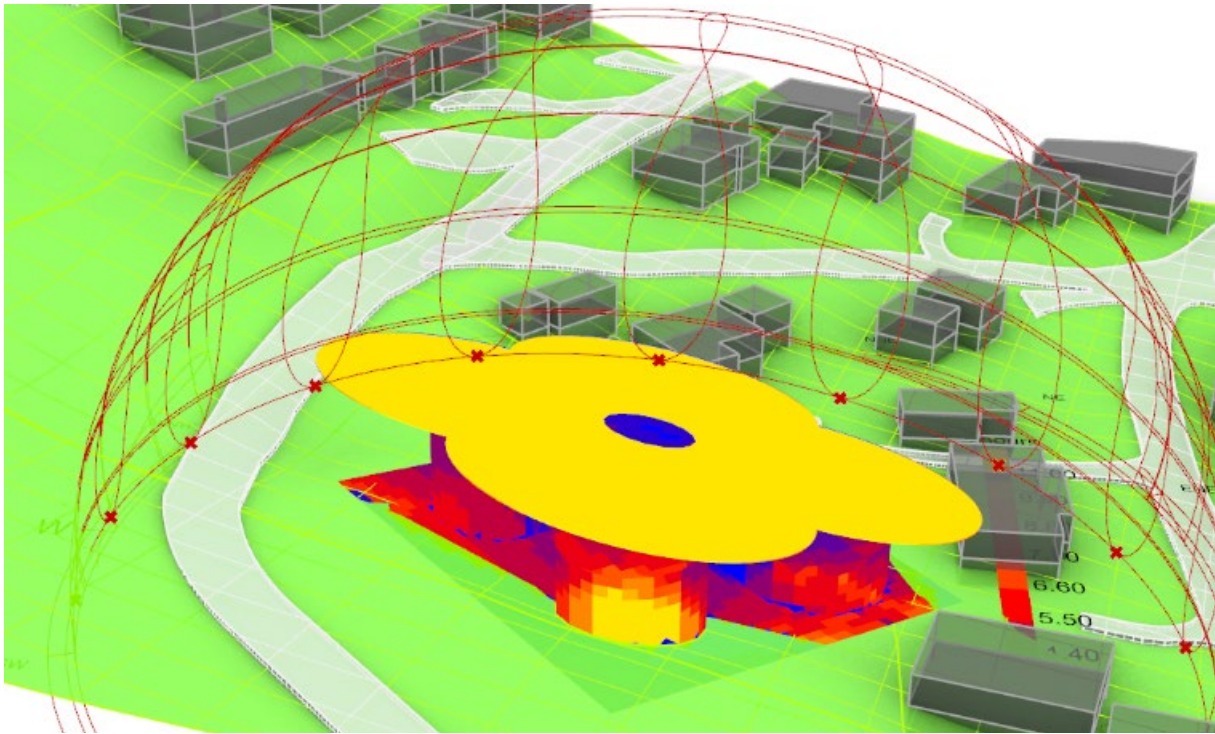


Figure 20: Parametric Solar study using Ladybug tool (by author, 2022)

After this discussion about how parametric design can tackle these problems to develop optimized solutions within recent developments, it is now the right moment to discuss the behavioural changes that must happen to common parametric design intent. This promotes a much more sustainable and social design result. Altogether, in order to achieve the goal that designers use parametric design in a way which benefits the future of the built environment. After taking sustainability, environment based and society-based ambitions into consideration with the concept of parametric thinking, these are the 4 guidelines for the use of parametric design to help solve future global challenges:

1. Environmental and Societal Data Collection and form-finding

In order to create a parametric system of operation which also covers societal and environmental matters, it is important to implement environmental and societal data collection. This in order to achieve a state where the shape of the object changes with social and environmental requirements.

2. Solution Optimization for Complex Design Problems

The goal of the designer should not be in the first place to achieve an aesthetic expression by means of parametric design, but rather a mindset which tries to achieve an optimization of solutions for societal and environmental matters within an integral design.

3. Performing Environment Based and/ or Society Based Design

By implementing Environment Based and/ or Society Based Design into the parametric design process, the designer becomes more aware of the interventions needed in order to achieve a better (social) built environment.

4. Practicing Circular Economy

By practicing Circular Economy, the designer becomes much more aware of the consequences on the environment in terms of finite resources, CO2 emissions, embodied energy and energy production.

The answer to the question how parametric design could be used for environmental and societal matters has to do with the fact that the parametric design intent has to change. Parametric design should be more focused on environmental and societal matters, rather than aesthetic expression. In order to achieve this, a set of guidelines for the use of parametric design to help solve future global challenges has been constructed within this research. The 4 guidelines consist of: Environmental and Societal Data Collection and Form-Finding, Solution Optimization for Complex Design Problems, Performing Environment Based and/ or Society Based Design and Practicing Circular Economy. This in order to create awareness for a sustainable and healthy future among designers.

Chapter 6 Conclusion Discussion and Reflection

Conclusion

The answer to the question how parametric architecture was approached in the past from Zaha Hadid Architects perspective all start with the visionary Zaha Hadid. She laid the foundation of implementing suprematism, deconstructivism, and cubo-futuristic style, inspired from Malevich's paintings and adapted this in a more 3-dimensional way of thinking and designing. This architectural style, in combination with the vision to achieve an integral design unique to its urban fabric and composition, asks for the need of digital design methods such as parametric design. Within her design method, the firm collects data through extensive research and through digital design methods such as parametric design, relations between elements are used to achieve an integral solution for complex design problems. This concept is well reflected in the Phaeno Science Centre, since the spatial, contextual and structural interventions in contrast to materialisation blends well in an integral design providing public spaces, functional efficiency, cultural value and a healthy research environment. This was realized for the first time with the help of parametric design methods and sets the pace for their future as one of the leading firms in parametric design.

The answer to the question how parametric architecture was developed can be summarized throughout this research. If we look back again at the development of parametric design, it has experienced many shifts in relevancy, feasibility, design approach and ambitions. In Patrik Schumacher's article about parametricism, he explains why it has become the dominant, single style for avant-garde practice today and why it is particularly suited to large-scale projects. According to this logic, Parametricism is the successor of modernism achieving new ambitions towards a digital-driven and complex society. These ambitions, however, were more focused on aesthetic quality rather than problem-solving techniques. After the decreasing popularity and criticism towards parametricism, parametric design was in desperate need for a redemption. The biggest shift of the parametric design approach is arguably after Schumacher published his second article about parametricism. Here he reinterprets the definition behind parametricism and pleads to give way to a focus on emphasizing functional principles and societal purposes, so the parametric design intent becomes more strategic, applied and performance oriented rather than focusing on expression. The switch is also relatively speaking the point where we are now. So, in order to make sure that it remains that way we are also in desperate need for guiding principles.

The answer to the question how parametric design could be used for environmental and societal matters has to do with the fact that the parametric design intent has to change. Parametric design should be more focused on environmental and societal matters, rather than aesthetic expression. In order to achieve this, a set of guidelines for the use of parametric design to help solve future global challenges has been constructed within this research. The 4 guidelines consist of: Environmental and Societal Data Collection and Form-Finding, Solution Optimization for Complex Design Problems, Performing Environment Based and/ or Society Based Design and Practicing Circular Economy. This in order to create awareness for a sustainable and healthy future among designers.

The answer to the research question *in what way should designers reassure that the use of parametric design can be switched from aesthetical purposes to problem-solving purposes for future global challenges throughout Zaha Hadid Architects' historical approaches and developments*, will now be explained. After analysing all the sub questions, in order to reassure those ambitions, it is important to change the parametric design intent into a more environmental and society focused process to get a more sustainable and social parametric design result.

Discussion

This research was based on focusing on Zaha Hadid Architects. But ZHA were not the only architectural firms to be pioneers let alone masters in the field of parametric architecture. In order to get a more reliable answer to the research question it is also important to find perspectives from other architectural firms and their relevant case studies. Also, it is not clear if parametric design is going to be the main architectural practice worldwide, even if designers remain having a societal and environmental focus. Altogether, more research is needed to get accurate results and to test this hypothesis.

Reflection

Looking back at the research I am aware that I needed at least more time to get a more personalized analysis of the case study, since I used more opinions from others than myself, and I lacked making analytical illustrations about the building. For this research my ambition was to understand the concept of parametric design better, so I get the basic theoretical knowledge on when and how to use it. But I do feel that after this research I understand the concept of parametric design better and I know how to practice it in a more sustainable way from a theoretical perspective, also surprisingly from input from myself. I am also very excited that I have officially participated in the academic discussion about parametric design and even proposed guidelines myself in succession of Patrik Schumacher's ambition. Also, I think that I achieved to answer the research question and altogether I am satisfied with the result.

About the author

The author of this architectural history thesis is born in Rotterdam, the Netherlands. He holds a bachelor's degree in architecture, Urbanism and Building Sciences in the University of Technology Delft's faculty of Architecture and he is currently doing his master's in Architecture.

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Figure 1

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