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# The Concept of Parametric Urbanism and Its Dimensions in Sustainable City

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**Abstract.** Contemporary sustainable cities are characterized by rapid development that include various areas of life and an increase in the rate of urbanization, which led to an increase in the complexity of cities as cities exhibit the characteristics of complex natural and organic systems. Many mathematical models have been developed to study the complex systems that also apply to contemporary cities. What makes cities a complex system is the interconnection of physical and organic components, including people. The concept of parametricity is one of the modern concepts in the field of urban planning. It is based on an algorithmic mathematical principle governed by the relationships and the connection between the subsystems that make up the overall system and facilitates effectively in making the urban planning process more flexible by reducing the effort and time spent in preparing and revising plans. The use of the parametric concept in urban planning previously was limited to being a digital technology, deviated from parametric thinking, design and model. As we mention above, there is a cognitive deficiency in the concept of parametric urbanization. The objective of this paper is to build a knowledge framework on the concept of parametric urbanism and the most important aspects related to it as we assume that parametric urbanism is a new approach at the level of urban planning. This done by the use of the analytical descriptive approach in researching parametric thinking, parametric design and types of the parametric model, the concept of parametric urbanization, its objectives and its social, urban, economic and environmental dimensions.

**Keywords:** Parametric Urbanization, Parametric, Parametric Reasoning, Parametric Design, Parametric Model

## INTRODUCTION

The term parametric is basically a mathematical term and the architect Luigi Moretti was the first to use it in design in the 1940s, when he wrote about parametric architecture as the study of architectural systems with the aim of determining the relationships between dimensions based on standards. Moretti also emphasized the correct use of mathematical terms such as parameters and that inaccuracy is more dangerous than ignorance of parameters. There are those who refer the origin of the parametric form to Antonio Gaudi. Gaudi studied various sciences such as mathematics, general physics and applied sciences, and this was reflected in his geometry, which was known as the geometry of curves, parabolas, spirals, and parametric pieces linked in a controlled manner. This appears in the dangling chains from churches restricting birds. These chains include all parametric equation (length of chain, location of anchor point, weight of bird cat) A set of results (different vertex locations of points on strings) that derive from parameters using explicit functions (in this case Newton's laws of motion) [1]. Technological progress and the use of digital programs in the architectural design process have helped the development of the term parametric at the level of architecture and the spread of its application around the world aiming to address social and environmental issues in the world. However, the advantages and possibilities of applying this term appear on the urban level more than on a single building [2]. At the urban level, the first attempts to use mathematical simulation systems were by (Haggett & Chorley, (1969). Then computer explorations developed for many years, leading to Bill Hillier's research on Building space, which studied the spatial shape of human settlements in 1976, which was in its first incarnation a proposal to develop a theoretical synthesis of cell agglomeration models. Then, at the regional level in exploring the spread of

limited aggregation models for urban growth and the computer applications were used at the level of design and planning, leading to the official announcement in 2008 by Patrick Schumacher who announced the parameters [3].

## Parametric Thinking

Parametric thinking is procedural thinking and not a stereotypical thinking. Thus, the aim of the type of output changes, whether at the architectural level or at the urban level, is to the production process of the output. This focuses on the relationship between the elements instead of the plurality of elements (materials or data) and thus the product. The final is the outcome of procedural actions that depend on linking tangible and intangible systems to a design proposal depending on the relationship between the properties of these systems

The parametric thinking is characterized in the academic and professional environment by its ability to reduce time and reduce pressure on designers through flexibility in making changes in the designs at any stage of the design stages by changing parametric values that set up determined by the designer or planned to achieve the desired goal. This will enable the emergence of a parametric design process, and therefore parametric thinking does not represent a single design solution or proposal, but rather an integrated set of solutions and options by focusing initially on the relationships between the elements more than the elements themselves. This leads to the presentation of multiple options and this is what parametric thinking differs from the traditional thinking method that focuses on the design of the product and how to achieve it[5].

## Parametric Design

The parametric design process is defined as a computer process to solve a problem in specific steps that depend on algorithms that take different forms (values, standards, rules, equations). These can be specific instructions that achieve a goal or set goals through the application of specific steps.

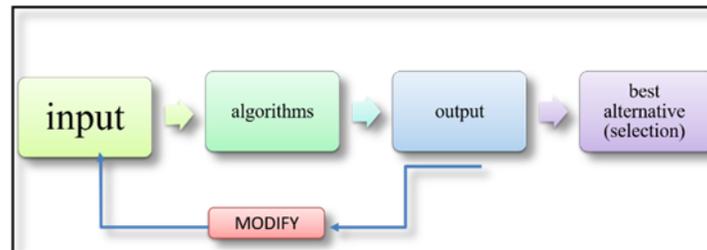


FIGURE 1. Stages of parametric designs

That is, the parametric design is formed by adjusting the parameters and revising the rules that must be determined precisely because they are responsible for the formation of the design and the success of the design solutions. So the parameters help in the formation of several possibilities by replacing the stable variable and the singular with the multiplicity and thus controlling the interactive behavior of the components and building systems to produce three-dimensional models Instead of two-dimensional drawings. This production is characterized by geometric similarity and change in the relationships and links between them. Thus the concept of parametric design is linked to the concept of variable design, which is characterized by flexibility, unlike traditional models that require greater efforts in order to make adjustments, whether mathematically or geometrically [6]. It focuses on the logic of generating design options and not on output as in the traditional thinking methods [7]. The process of forming the parametric shape goes through certain stages, as shown in FIGURE (1)

- Entry stage (input): Set the parameters and define the relationship between them
- Generation mechanism stage (algorithms, equations, links, or rules)
- Production director (output)
- The stage of choosing the best alternative (selection) [8].

The FIGURE 2 shows that the difference between parametric thinking and parametric design lies in that parametric thinking focuses on the process of producing the goal and not reaching a predetermined goal. This means it focuses on the starting point to produce multiple options instead of following multiple methods to reach a specific goal through

dealing with the interrelationships of the elements either. They were numbers or data instead of repeating the same elements, and it is the first step of parametric design, which means designing algorithms that can be in the form of values, equations, or rules that pass through four stages that include entering parameters and determining the relationship between them. It then formulates algorithms to result in multiple outputs. The best output is chosen and continued. This process repeats revising and modifying the values of the algorithms to reach the best outcome

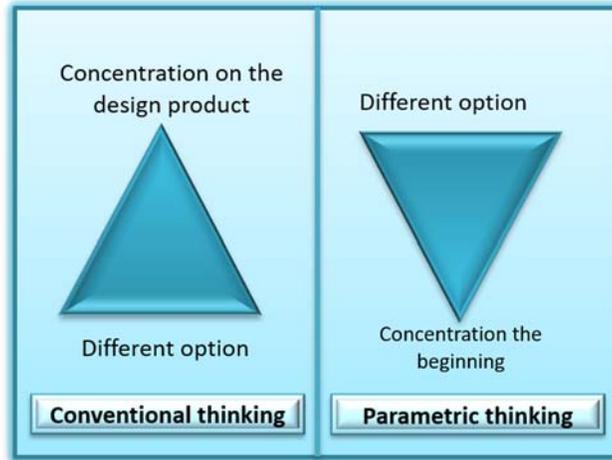


FIGURE 2. Different between conventional and parametric thinking

### Parametric Model

In the past few years, parametric models have become standard tools that work on describing and producing alternatives. The process of creating the parametric model is the first stage of the parametric design in which the variables are defined and the data are represented by one of the numerical tools such as:

EVIT 3DMAX, RHINOCEROS, GRASSHOPPER, CITY ENGINE [9]. In a program GRASSHOPPER, we deal with the graphic algorithm shown in FIGURE (3), which consists of nodes and links, and the nodes consist of three parts that represent the first part of the entry and contain several slots known as input slots, the number of which varies according to the required operation. In the graphic representation process, the input area consists of three slots that represent (X, Y, Z). The middle part represents the name of the operation to be performed, while the last part represents the output which contains the output slots whose number varies according to the process. In the graphic representation process, the output process consists of one slot representing a point resulting from the input coordinates, i.e. the number of output slots depends on the type of operation and the nodes are interconnected in between them. This connection is by means of the links to the outputs of a node to become the inputs of another node that performs another process, and by changing the location of the links between the nodes and the formal output changes. Also, the nodes and links constitute the whole algorithm [10].

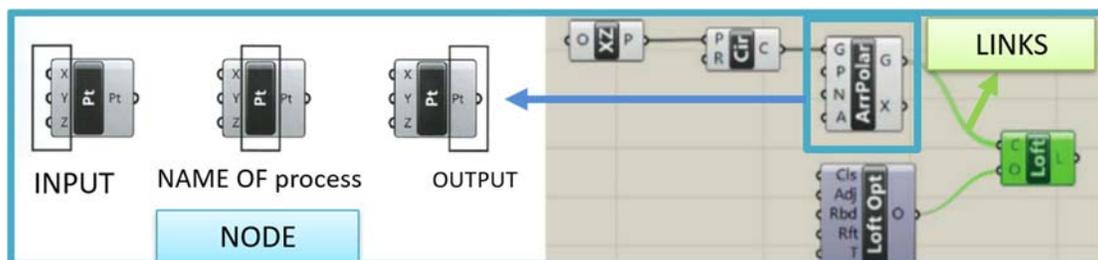


FIGURE 3. The forms of Algorithms in GRASSHOPPER

There are two types of parametric models:

**Parametric variable model:** it aims to build a model that controls configurations by changing parameter values without changing the topological properties of the elements.

**Compound parametric model:** is intended to build a model that consists of a series of varied shapes in terms of the number of elements and interconnections. It focuses on the relationship and the way of interconnections between the parts of the formation<sup>7</sup>. The model parametric compound is best suited to urban planning and urban design, which is determined input values and deal with the bond of relations between these inputs, whether logical relationships or sports to determine the output. For example, the main parameter of the ways is the street width that determines meters, but to change the this parameter, It affects not only the street, but also the other parameters that are related to it, such as how the road is paved, the structural system followed, and the radius of curvature of the road [11].

Several computer programs (such as REVIT, 3DMAX, GRASSHOPPER, RHINOCEROS, RHINOCEROS CITY ENGINE, AUTODAC) were developed to apply the parametric model that deals with multiple types of parameters starting from independent to dependent and related, logical and conditional. These programs are two types, either a variable model which means changing the values of the parameters without changing the topological characteristics or the complex model which is considered the most appropriate for urban planning because it focuses on the relationships between the parameters. These complex models are used for several purposes: improving the environment, achieving a desirable function, improving the distribution of land uses, implementing a specific policy for developing the area and for urban expansion. This complex interaction needs adapting a parametric approach which is achieved through adopting parametric thinking, parametric design and using the parametric model ach as shown in FIGURE 4[10].

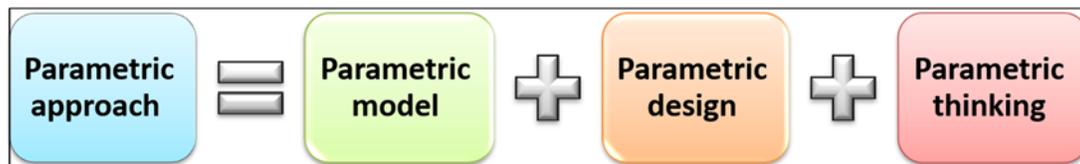


FIGURE 4. Parametric approach

### Parametricism Styles

In general, styles carry the aesthetic memory of the period in which they arise, and style is defined according to the dictionary of architecture and construction as a classification of the design product that shares certain features such as the similar general appearance and how the design is formed and designed in a specific time period and geographical area. The most important characteristic of the modern era is technological developments in various areas of life so it can design described parametric as a reflection of the technological developments of digital system. It has led to a change in the design processes, the tools used and the formal relations and thus the parametric design inspired by the idea of the emergence of approach a new result of the digital revolution is known as Parametricism. It is characterized as a global style that can be used all over the year due to its reliance on digital technologies [12]. In 2008, a new method was launched by the offices of Zaha Hadid and Patrick Schumacher from the London School of Architecture as a serious style with its roots in digital animation techniques. It has been developed over a period of fifteen years associated with digital design tools and is considered a fitting style at all levels from architectural and interior design to urban design on a grand scale. The larger the project size is, the more efficient its application becomes. Parametric concept differs from parametric design as the concept that depends on the perception of how to construct the parameters that produce the design and not as a design concept. This means that it is not necessary to adopt advanced parametric techniques to produce centralized parameters, and this is explained by Zaha Hadid's work that did not use parametric design [13].

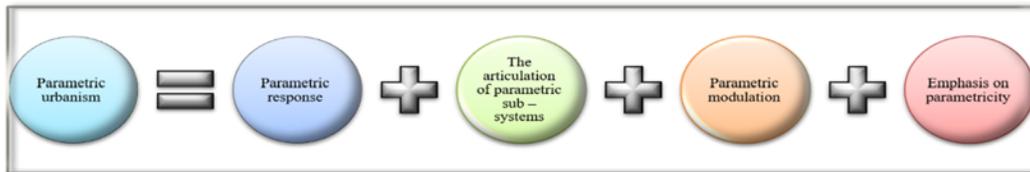
#### *Aims of the Parametric Urbanism*

Parametricism has several aims to expand the scope of applications encompassing several aspects and not limited to the technical side only:

- The articulation of parametric sub – systems: these systems aim to move from a single system to interconnected subsystems programmatically
- Emphasis on parametricity: the aim is to promote organic integration through mutual relationships that emphasize distinction and individuality, which leads to enrichment of the visual environment and makes it more expressive.

- Parametric modulation: the goal is to build complex configurations with multiple readings based on sensitive parameter variables. Any change in these parameters leads to a change in the way of perception.
- Parametric response: the aim of it is to create an urban architectural environment that is responsive and adapted to the change of time
- Parametric urbanization: the aim is to design urban variables for masses, distances, and directions. Any modification of these variables affects the existing urban environment and the deep relationships between its various levels. These levels can be such urban, architectural and the internal organization of blocks to achieve integration in the urban environment (i.e., parametric urbanization deals with parametric articulation, parametric modulation and parametric response as tools achieved through the application of strong urban relationships [14].

From the aforementioned, parametric urbanization is the main goal of Parametricism, which includes the achievement of the four previous objectives. FIGURE (5) Parametric objectives and the relationship of parametric urbanization to other goals



**FIGURE 5.** Aims of Parametricism

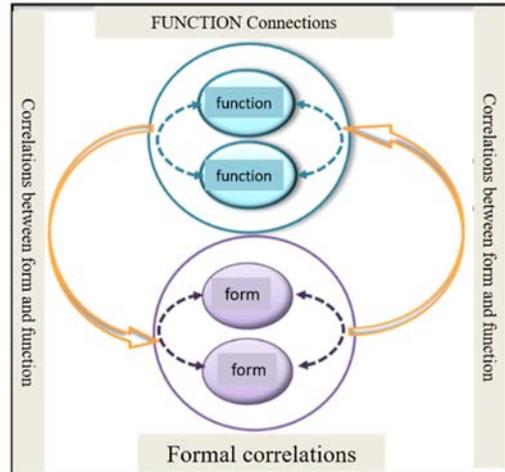
## **PARAMETRIC URBANISM:**

This urbanism is a new trend in urban design and depends on the digital modulation for the design of innovative urban spaces engineered and vital socially based on the changes of the formal and functional environment. It aims to generate interconnections urban engineered tailored to the natural terrain, It is adapted to the pre – urban connections existing in line with the complexity that it is an urban environment. Contemporary cities need a more dynamic approach to deal with this complexity, as the urban interconnection, in light of the parametric approach, is interconnected subsystems with relationships characterized by complexity, intertwining and interdependence. To achieve or bring about a change, this is done by changing the parameters that include the planning structure, and this means controlling the activities of life, urban spaces and their modification by controlling the formation, organization and performance of urban spaces, uses, activities, interfaces, structures and infrastructures [3]. After reviewing the literature that dealt with parametric urbanization, we find that the most important characteristics of parametric urbanization.

### **Characteristics of Parametric Urbanism**

#### *Interconnections*

Relationships are the links or the main feature of the parametric setting. The parametric model control has been the concept of link recognized link between form and function. Form follows function and is a response of social interaction that takes place within the space became this social dynamic link equal bilateral unity of (form, function and beauty and utility. Thus, relationship between beauty and utility and became a deep relationship which cannot be separated. This relationship is based on the function of biological organisms that are attracted to all that would benefit life and resist what threatens it. This means that the relationship of beauty and function is Positive and the sense of beauty is responsible for the sense of organization[15] . Three types of relationships are shown in FIGURE (6).



**FIGURE 6.** Types of connections

FORMAL correlations: Relationships between formal subsystems

FUNCTION Connections: The interdependence of functions to achieve social communication

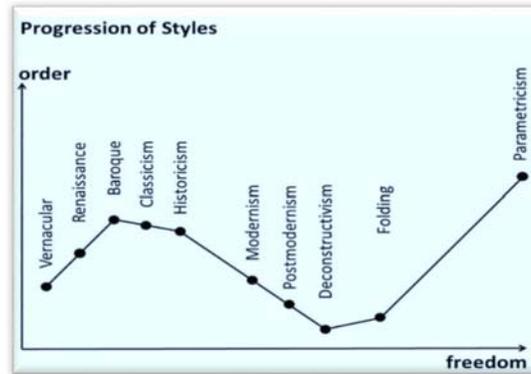
Correlations between form and function: to create spaces to live in and not to pass through only by studying the prediction of pedestrian and traffic patterns, places of assembly and public squares [13].

#### *Differentiation:*

The main slogan of the parametric is continuous differentiation. It is not just a diversity but rather an adaptive curriculum variation that leads to the formation of a parametric dynamic that includes all levels such interior design penetrating all foundations of discipline to generate a flexible structure that is adaptable to its contexts. Thus, the parametric flexibility of the elements and the adoption of modified systems happen in a sequential manner according to the principle of cause and effect rather than recurring systems. It produces rhythmically organized and distinct shapes continuously [16].

#### *Freedom*

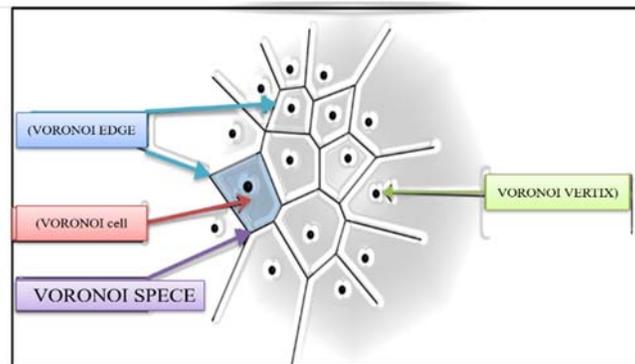
Parametricism aims to establish a system of urban free originates from the local identity and enhances the sense of belonging to the context through compatibility with natural and social features. These features generate the identity of a unique urban and this freedom does not mean the chaos but coincides with the order and arrangement contrary to what preceded modernity and what postmodernism. FIGURE (7) shows the strength of the relationship between the order and the freedom and shows parametric the highest value of this relationship. This value is the concept of freedom in the light of the urbanization parametric conditional commitment to the system and freedom from political forces and bureaucracy based on the bottom-top design. It avoids simple unified repetition to produce incomplete open-ended parametric structures that depend on the connections between subsystems, that is, they are relational structures more than they are engineering [17].



**FIGURE 7.** Strength of the relationship between the order and the freedom

*The implicit symmetry with nature*

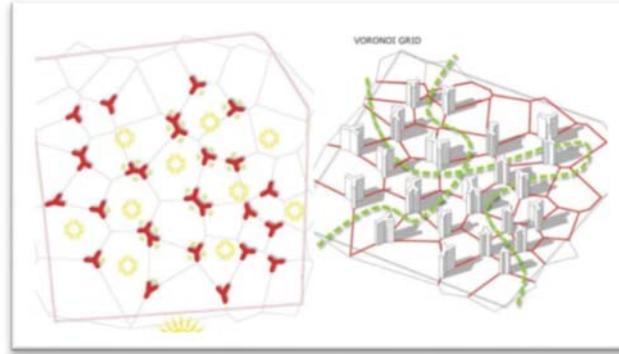
The implicit symmetry with naturalism in the light of parametric urbanization is at the first two levels (the formal level), as the parametric structures are similar to the natural structures, whether organic or inorganic resulting from the self-organizing processes. These forms are known as the voronian structures. Voronoi diagram expresses many of the natural structures that are characterized by their complexity and consisting of centers that represent the core of the shape and edges (VORONOI EDGE). These edges form the (VORONOI CELL), the (VORONOI VERTIX) and the (VORONOI SPECEAs) shown in FIGURE (8).



**FIGURE 8.** Voronoi diagram

It can exist in two- or three-dimensional dimensions depending on the repetition and proximity of the Voronoi cells that are formed by adopting shape-generating algorithms that produce shapes that express nature and living organisms and are governed by mutable parameters. These parameters are the size, scale, number of edges, and the position of the nucleus in each cell that is affected by the neighboring cell and considered edges Cells and their centers are the parts most sensitive to change, as shown in FIGURE (9). This FIGURE shows the concentric interconnection between the nucleus and the different cells and the peripheral interconnection between the common edges, and this is what achieved the second level (the performance level) [18]. It includes analogy with the interconnectedness systems and the internal organization of nature, which is considered the basic condition for a sense of beauty achieving clarity of visual performance related to the social performance of the built environment. This is known as the crowding system. The system depends on the collective behavior of self-organizing decentralized systems. It consists of simple elements or bodies that interact with each other and with the surrounding environment. This happens despite the lack of centralized control producing its own behavior, such as flocks of birds or ant colonies characterized by the evolution and complexity of the system that deal with the holistic behavior than that of its individuals[19]. The above discussion shows that parametric urbanism is characterized by interconnectedness, differentiation, freedom, implicit symmetry with nature. These characteristics give a vision of the urban form in light of the parametric concept within a

mathematical relational framework based on the parameters that control the achievement of these characteristics and affect the physical, social, environmental and economic dimensions that will be discussed next.



**FIGURE 9.** The interconnections between the edges and cores in the Voronoi diagram

## Dimensions of Parametric Urbanism

### *Urban Environmental Dimension*

Urban environment of the blocks and the space is formed and the space is the basic building block of the urban environment. According to the parametric urbanization, the concept of space is changed into the field. This area is like what physical space or filled area with fluid, which is a dynamic field continuously variable, and this is what gave a sense of the system. This system can not be limited to regulate only the physical elements and thus become a series of interrelated areas of continuously chaining. The interior of the urban environment differs from its exterior and focus on the events and activities held therein more than the formal formations thereof [20]. This is to allow the visibility of larger possible number of events and participations in them and to give many additional options to determine the next step. Thus, the functional system is an aesthetic product. For Alberti, beauty is harmony resulting from an arrangement based on a mathematical principle governed by relationships, so the field of vision becomes rich and organized at the same time and gives evidence and projections behind the visible layers[21]. Thus, the process of awareness of the environment and urban became momentum depending on the physical variables responsible for changing the visual perception that gives meaning and impression of the urban environment [22]. In addition, the formation of buildings in the urban body and orientations not only affects the process of cognition but also the environmental furthest adoption of urban patterns and architectural formations that are constantly changing to adapt to environmental conditions. This gives the urban body aesthetic distinctive membership and helps to be flexible urban environment adapted to climatic conditions by controlling building façades and improving architectural forms according to environmental parameters such as a map of solar radiation throughout the day. So, the facades of buildings change in a way that adapts to the change of solar radiation, resulting in an urban interface that is constantly changing dynamically [23]. In order to achieve the urban and environmental dimensions of parametric urbanization, some paths are to avoid. These paths are called the negative induction that do not correspond to the essence of parametric urbanization and to emphasize the positive inference to provide guidelines and techniques to rapidly advance parametric urbanization<sup>12</sup> as TABLE 1, shows:

**TABLE 1.** The positive and negative inferences for the urban dimensions of parametric urbanism

Design Inference	
Positive inferences	Negative Inferences
Adopt soft shapes by their nature (adopting curved and hybrid shapes)	Avoid rigid, inflexible shapes (avoid familiar patterns)
Adopt the gradient regimes (sub - systems to be interconnected total system)	Avoid platonic shapes
Support for linkages between subsystems	Avoid right angles
It is not possible to add or subtract any element except in the presence of articulation	Avoid straight lines
	Avoid minor repetitions
	Avoid isolation between elements (i.e. no relationship between elements)

Social and Economic Dimension

The social system development is lined to the urban environment where this development gradually with time. In addition, the most important is modern societies is the growing social complexity resulting from the diversity and density association relationships between events and daily activities. So, the activities in the society is a communication process [13]. The societies that inhabit large cities are known as the contemporary information network community, which consists of several networks that may be professional, cultural or commercial networks whose members communicate with each other. This is the basis for the modern economy, where these networks in the suburbs are weak and there is a disconnection between them and the city centers, which leads to accumulation in cities and the creation of a continuous dynamic communication state based on the methods of communication between commercial, professional and cultural networks. In turn, the urban environment becomes an interface for multimedia communications, whether it communicates via mobile devices or face-to-face communication, which is considered a measure of the individual's daily productivity. This has led to the difficulty of separating work and leisure times, and it is necessary to connect to the Internet 7/24, which pushed to live in cities and put more pressure on centers. Therefore, all community problems are communication problems, where social competence is related to communication efficiency, and to raise social competence is done through social parameters that frame and arrange this social communication. These parameters deal with individual behaviors within space and transform them into parameters such as how people flow. Where they gather, the relationship between pedestrian, traffic and how to perceive the surrounding environment<sup>24</sup>. These social and economic have consequences to avoid. They are negative functional and other paths must followed because they are positive t functionally. The TABLE (2) shows the most important functional inferences of positive and negative social and economic dimensions of urbanization parametric [12].

TABLE 2. The positive and negative inferences for the social and economic dimensions of parametric urbanism

Functional Inference	
Negative reasoning	Positive inference
Avoid fixed and fixed functional distribution Avoid segregation of jobs	Adopt communication between activities and events Deal with all the functions on it parametric variable scenarios

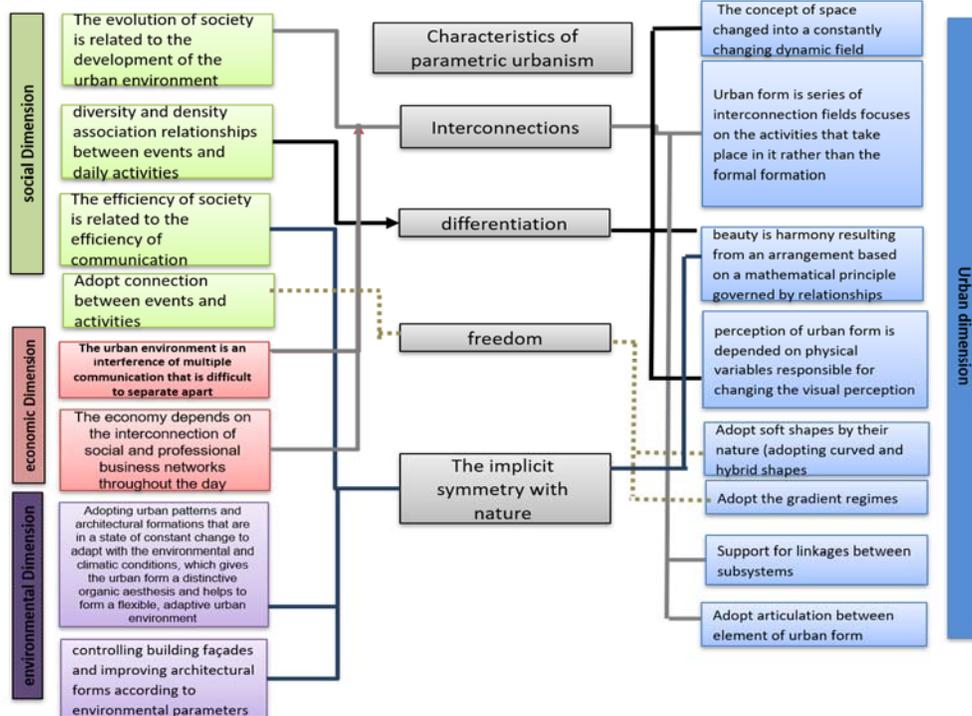


FIGURE 10. The relations between the parametric features' Parametric dimensions

## CONCLUSIONS AND RECOMMENDATIONS:

### Conclusions

- The concept of parametric urbanism is one of the most important modern concepts in the field of planning and urban design because it provides flexibility in dealing with data. It reduces time effort in preparing plans. It depends on an algorithmic mathematical principle based on relationships and correlations. We can say that the concept of parametric urbanization represents a shift in planning thought by directing the task of planners. Designers are drawn to design algorithms and their interrelationship, and not focus on the output and how to reach it, as happens in the traditional way of thinking
- Parametric urbanization can be achieved by adopting a parametric approach achieved through following parametric thinking based on linking tangible elements and following a design method based on the design of shape-controlled algorithms. These algorithms consists of four stages (the input stage, the algorithm generation stage, the output stage, and the optimal selection stage ) adopting one of the digital programs such as (Revit, grasshopper, Maya, city engine).
- The research showed that the most important characteristics of parametric urbanization are the connection that includes the formal and functional connection with the interconnectedness of jobs and their convergence and formation of places for entertainment. These features work in one place and the functional formal connection leads to the formation of livable spaces and not for traffic only. The differentiation characteristic w means that the city is formed from interconnected systems in a variable and flexible manner at the same time, which affects the perception process that can be controlled through parameters and the characteristic of implicit symmetry with nature, which emphasizes the similarity between the urban system and natural systems in terms of performance, form and freedom that assures that freedom in light of parametric urbanization is framed by the system

### Recommendations:

- Expanding the study of the concept of parametric urbanization and how to adopt a parametric approach to planning the urban body due to the importance of this topic in the planning process.
- Enlarging the study of parametric models and digital software specialized in producing parametric configurations to select the best model at the urban level and the appropriate program for each aspect of urban planning.
- Holding educational courses on modern digital technologies that can be used to prepare plans targeting students and professionals in the field of architecture, design and urban planning.
- Increasing the extraction and testing of parameters affecting the urban body at its various levels, such as the micro level, the intermediate level, total level, and the common parameters between all these levels.
- Expanding the common parameters among the dimensions of the urban body such as physical, functional, cognitive and the social dimension, being one of the important issues.
- Conducting a detailed study of the interconnectedness property that is the main characteristic on which other parametric characteristics depend. These characteristics can be summarized as an approach based on the correlations between all levels and components in a diverse, differentiated manner that converges with the natural system in formation and function within an organized framework .

## REFERENCES

1. Davis, DA, History of Parametric, AUGUST 6, 2013. Retrieved 5 April2020
2. Samalvicius, A. LIdeology as geometry: a note on parametricism and its theoretical foundations. *Culture and Science*, (2020).
3. Mohamed S, & Khalid SM. and. *Al-Hagla, Parametric Urban Comfort Envelope An Approach toward a Responsive Sustainable Urban Morphology*. Paper presented at the Sustainable Urban Morphology Conference. . (2012).
4. Fusero, P. L. M. Parametric urbanism Anew frontier for smart cities. *Journal of Urbanism*. (2013).
5. Karle, D., & Kelly, B. M. *Parametric Thinking*. University of Nebraska Lincoln (UNL): College of Architecture. (2011).

6. Stavric, M., & Marina, O. Parametric Modeling for Advanced Architecture. *International Journal of Applied Mathematics and Informatics* 5(1) .(2011)
7. Hernandez, B. Thinking parametric design: introducing parametric Gaudi, *Design Studies*, (2006).
8. Morshedi, S. J. K. *the impact of technology of digital contemporary architectural form (the role of the surfaces of the derivative strategy digitally in the form characteristics Almmari- Iraqi Architecture Case Study)*. (Master Unpublisheed). University of Engineering Technology, Department of Architecture. (2017).
9. Alafandy, A. F. D. A. K Specifications for Building a Parametric Model in Digital Architectural Designs. *Journal of University of Babylon for Engineering Sciences*. . (2018).
10. Tedeshi, A. (2014). arametric architecture with Grasshopper.
11. Cantrell. Bradley and Adam Mekies, *Codify Parametric and Computational Design in Landscape Architecture*, 2020 ,P105
12. Oktan. Selin, R A, *Parametricism: a style or a method*, Karadeniz Technical University. Conference: ARCHTHEO '17 / XI. THEORY AND HISTROY OF ARCHITECTURE CONFERENCE (2017).page 67
13. Schumacher, P. (2008). *Parametricism as Style - Parametricist Manifesto*: London. Retrieved 5 /10/2019
14. Leach, N, *Digital Cities Architectural Design*, (2009).
15. Pun, A C, *HParametricism: The "Style" of Future ? Architectural History and Theory Global Perspectives* , (2011).
16. Rahim, A H J, *Elegance in the age of digital technique architectural Design* , (2007).
17. Çalışkan, O, *Parametric Design in Urbanism: A Critical Reflection*, (2017).
18. Bahrami, N F K B, *Application of voronoi diagram as an architectural and urban planning design tool*,(2015).
19. Al-Saidi, Islam Magdy Taher, Usama Yusef Muhammad, Yahya Abdul-Rahman Rashid *Parametric design as an introduction to nature's inspiration for product design* , research published in the *Journal of Science and Arts* 2019
20. Schumacher, P. *he Parametric City*. London. . 2010 Retrieved 7/11/2019
21. Schumacher, P. *Parametricism with Social Parameters*. London 2015. Retrieved 5/12020
22. Basu, T.. Mainak Ghosh, *Visual perception of space and parametric design: A brief discussion GSTF. Journal of Engineering Technology*. (2017).
23. Hussein, M. M, *The Effect of the Resilient Urban Form on the Resilience of City* Paper presented at the The 1st Scientific Architectural Conference for Postgraduates' Researches (2020).
24. Schumacher, P. (2012). *Parametric Order – Architectural Order via an Agent Based Parametric Semiology*. London. Retrieved 5 April 2020.