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Research Article

# Wooden Structures within the Context of Parametric Design: Pavilions and Seatings in Urban Landscape

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**Abstract:** Today, on the one hand, while the traditional design process continues, on the other hand, digital design systems along with advances in computer technologies continue to present designers with new and effective ideas. Parametric design is preferred by designers for its relationality, contributing toward versatility, ensuring flexibility, simplifying diversification, and for presenting programmatic solutions. As is seen in a number of areas, we have also begun to encounter the use of parametric designs produced with parametric design systems and wooden materials in urban landscaping. The purpose of this study is to examine the upper cover application and seating elements generated by taking advantage of parametric designs from wooden construction materials in urban landscaping areas, and examine the impact of wooden material characteristics while generating behavior and parametric structures of technologies. After researching parametric design and wooden material concepts, an attempt was made to reach conclusions through analyses conducted by examining parametric wooden designed pavilion and seating element specimens applied in various regions of the world.

***Keywords:*** *parametric design; wooden structures; pavilion; seating; materiality*

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## 0 Introduction

Nowadays, while developing design methods and mediums, on the one hand, material diversity and technology renders it possible to generate infinite versions in a much shorter period and ensure many possibilities. It provides the opportunity to focus on new research in generating design models, in developing computer technologies (digital design) and the visualization of ideas in the architectural field. Digital methods have brought "morphological factors" such as geometry, composition, and algorithmia to the forefront with different techniques and methods, turning the concept of parametric design into an important matter. In this context, the parametric design has gained importance in determining the relationships between various parameters of architects' design models. With the ability of designers to change a few parameters and to update the remainder of the model in a sensible manner according to the previously determined rules, thus presenting designers the opportunıty to achieve more control and capacity.[1,2]

Although the use of wood as a natural material and contemporary industrial product constitutes some limitations, glulam wood allows for curvilinear form designs of greater volume to be planned.[3] While passing into a limited space with the use of traditional wooden materials, not only can a much greater space be covered with today's parametric design possibilities, a more resilient product is also obtained. With these design opportunities, the use of seating and pavilion elements utilized in urban spaces in related studies is taken up from a standpoint of parametric design whereas selected specimens have been assessed in the context of parametric pattern, formation, structure, material, and tectonic order.

## 1 Purpose and method of the study

The subject of this study suggests how wood can be diversified with parametrically designed possibilities, especially in outdoor spaces, when used effectively among other types of materials. With this goal in mind, the technical characteristics of wooden material were defined, their affinity with parametric design was established, whereas specimens from various regions around the world were analyzed through a study of prepared tables of subjects among criteria considered to have an influence on parametric design such as functionality, structure, and materials.

## 2 Parametric design and components

In regard to essential matters such as design processes, approaches, tools, forms of production and form space structure relationships, and architectural design have always undertaken an effort of self-renewal. Nowadays, digital design tools play an interactive role in architecture, as the process of architecture redefining itself has begun. Together with the increasing effectiveness of the parametric design process, these tools have continued to evolve into a situation that also affects architectural designs to the extent that architects practically refer to them as "assistant designers." Gerhard Schmitt suggests that the era in which computers are used as a vehicle has come to an end that computer will influence design as "partners" in the upcoming period, and results of the parametric design process have become a reality through the combination of both human and machine intelligence. In this context, the computer has gone beyond being a mere drafting or presentation vehicle to become an assistant designer that influences the design process.[4]

A parameter is a quantity that is defined for a situation and can be altered. The situation that holds this quantity as one or more within it is perceived as parametric. The number of parameters may vary depending on the situation. What is important is to establish the relationship between these parameters, and to be able to manage these parameters on demand. As a method, parametric design is the situation of giving direction to design, depending on some variables. The form of the desired product to be designed is determined by entering it into the computer software, whereby it is possible to make different changes to the determined form and produce multiple variations of this product. Flexible design possibilities allow the design to be flexible and to obtain different planes of the surfaces in the desired directions, whereas value changes provided at the design's X, Y, Z axis can facilitate almost infinite flexibility in form and surface formation. In places where changes are required in size, angle, and thickness, parametric values are altered, whereby various solutions based on a single principle detail solution may be created [Figure 1].

In design, a parameter is defined as a factor that defines a system and determines or limits its performance.[6] Parameters bear importance to manage the rules and generate variations according to them. Qualitative, qualitative, and imaginative that can determine architectural quality can generate said parameters. Physical or digital, they are the building blocks of any design. They can be differentiated by measurable factors such as heat, pressure, distance, or by abstract factors such as structure aesthetics. There are no rigid form, no simple repetition, no unrelated elements, and all forms are soft (intelligent: Information = deformation), all systems differentiated, and all systems are correlated in parametric design.[7] Form and formation, structure and materiality are important components in the parametric product design process.

### 2.1 Form

A shape is manifested through movement from an architectural thought. Equality and equations define relations between geometries, creating dynamic interactions between forms, whereby interactions affect the behavior and possible form transformations. Having conducted important studies on parametric form interactions, Burry once again examined changes and transformations according to parametric rules of objects with certain parameters attached that passed from two-dimensional (2D) to three-dimensional (3D) in his work on the parametric theory he called "paramorph." According to burry, parameter-based design possesses a unique and unmatched ability such as defining, determining, and rearranging geometric relationships.[8] While generating a results-oriented form of traditional design, it forms a process-oriented shape in parametric design referred to as "finding form." Terzidis gathers shapes in five conceptual categories, mainly, caricature, hybrid, (un)folding, warped, and kinetic forms [Figure 2].[9] Modeling to be generated with these forms is based on associative rather than descriptive geometry principles. Relationships of forms to each other may vary depending on the designer's preferred

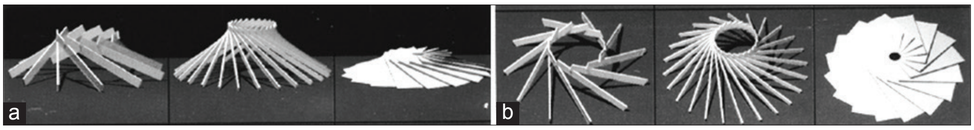



**Figure 1.** (a and b) Parametric modeling of a structural system; alternatives are generated as parameters such as number, slope, and height of the units are changed[5]

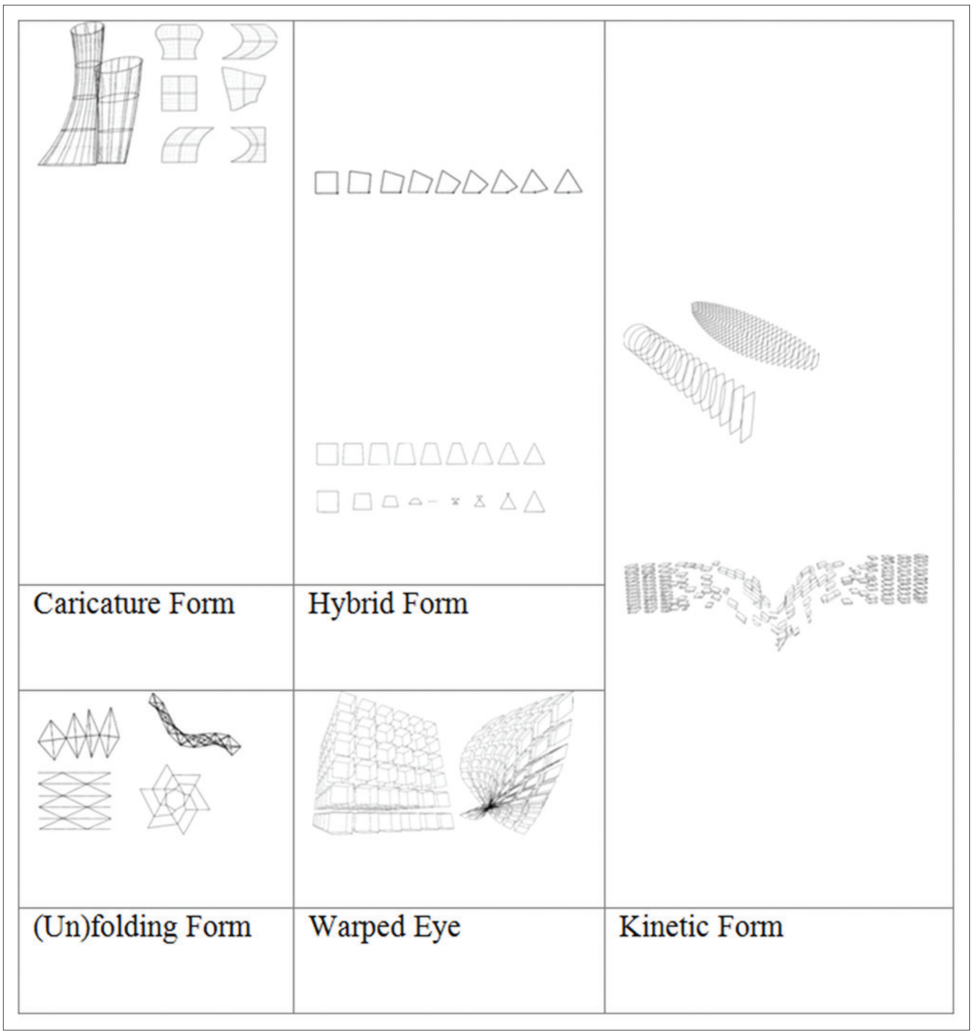



**Figure 2.** Shapes generated in a calculated environment according to Terzidis[9]

metric values. While the whole shape of the parametric product is undetermined, the pieces it is comprised are definite shapes.[10]

All geometries and algorithms such as “L” forms, “Splines,” and Nurbs used in the digital design can be utilized in parametric design alongside parametric geometries. On the other hand, if designers deem necessary, they can use non-morphogenesis and genetic development and change methods in developing their shapes and geometries. The propagation-based method is a simple form of parametric modeling. It has a number of advantages for modeling as well as overall shape control. While algorithms can calculate everything numerical or genetic by means of continual upgrades, they can organize and put limits on the remaining portion of the layout. Consequently, it ensures the generation of the main shape by repeating and transforming a single geometric shape with different variables. In the course of design progression, arrows (lines) create diagrams comprised secondary points at a lower level. Each node has a name and property in parametric modeling. Points can be considered as data-content objects housing design-related restrictions within them. Each property is accessible and has a value associated with the others. Each value is added in the context of certain relationship with other layouts. The parametric definition of shapes

(parametrics) allows complex and twisty surfaces to be presented in a versatile way.
Concepts of permanence and stability, once accepted as the basis of 20th-century architectural discourse, have been replaced with the concept of variability and dynamism along with the idea of parametric design. In an architectural sense in which the claim of finding the ideal final form is steadily losing ground, the shape is being defined as the freezing of any moment within its own formation cycle or emerging as an emergent.

## 2.2 Structure

In digital design, chain curves, non-uniform rational lines - nurbs, bending, and minimal surfaces can be effective in structural modelings of the geometric design process.[11,12]

### *2.2.1 Chain curve (catenary)*

The curve occurs from the shape that hangs beneath its own weight by two fixed ends. In the chain curvilinear model, the structure geometry is formed by the self-organizing of the rope hanging from two extremes, released only by its own weight, without external influences, featuring topological continuity [Figure 3].

### *2.2.2 Nurbs (non-uniform rational b-splines)*

The non-uniform rational principle is the line of the curve. Nurb curves consist of many control points and node vectors [Figure 4].[14] NURBS possesses the ability to create a wide range of geometric forms, from straight lines to platonic solids and extremely complex sculptural surfaces. For instance, with its definition of surface curvature grades, it is possible to reconstruct a complex surface with double curvature by rationalizing by means of algorithms, with straight or single curvilinear panels.

### *2.2.3 Curvature*

The axes possess zero area and general bending. Bending is only external bending; they are naturally linear and only feature bending whenever positioned to the Euclidean axis [Figure 5]. Convex surfaces are like spheres; they bend positively. Saddle surfaces are like hyperboloids in that they bend negatively.[14]

### *2.2.4 Minimal surfaces*

The technical description of a minimal surface is that its zero surface means bending. Minimal surfaces are represented by the catenoid, formed by the oscillation of the chain curvature bending around axes, having completely equal mutual bending, the Helicoid, formed with the oscillation of a line that simultaneously twists and turns, the Enneper surface, and the recently discovered Costa-Hoffmann-Meeks surface [Figures 6-9].


**Figure 3.** (a-c) Catenary Model, Shellstar Pavilion, Wan Chai, Hong Kong 2012, 8 m×8 m×3 m[13]

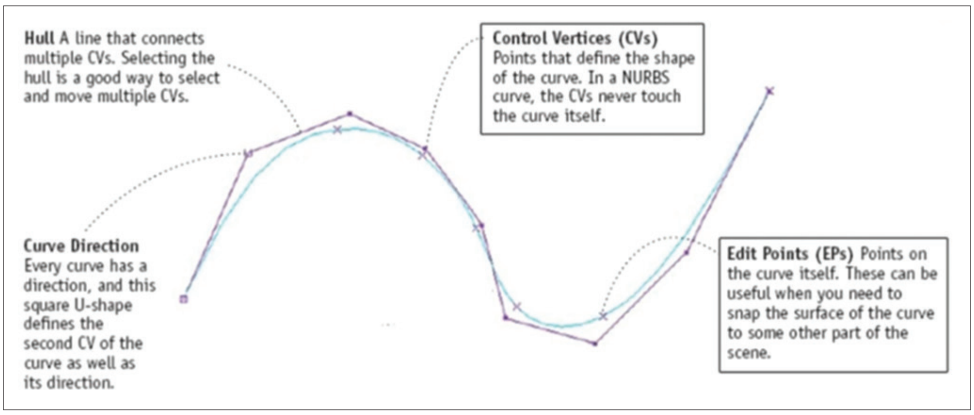



**Figure 4.** Schematic representation of Nurbs[15]

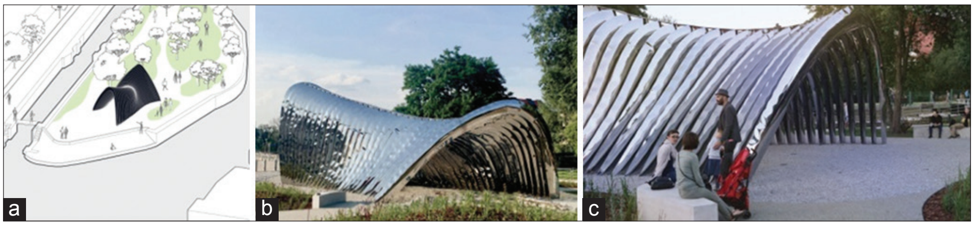


**Figure 5.** (a-c) NAWA design, Daliowa Island[16]

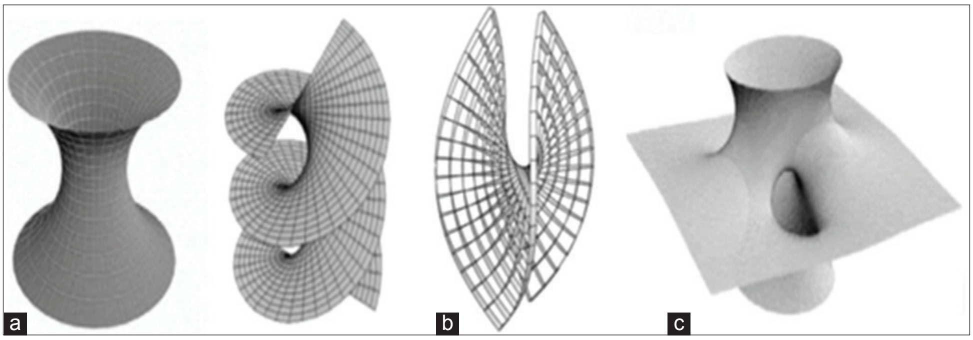


**Figure 6.** (a-c) Catenoid, helicoid, enneper, costa-hoffmann surface[12,17]

**Figure 7.** (a-c) Catenoid form, inside\out research pavilion at the central campus of the TUM, Munich[17]

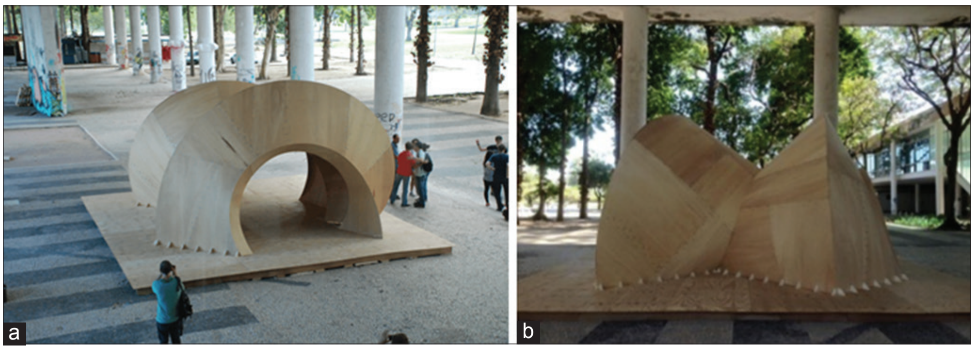


**Figure 8.** (a and b) Helicoidal surfaces, butterfly gallery, Universidade Federal do Rio de Janeiro, Brazil, 4–14 August, 2015, Andrés Martín-Pastor, Juan Expósito Bejarano[18]

## 2.3 Materiality and tectonics

Materials have indigenous qualities. People seek methods of making structures exceed the readily available limitations of materials as found in nature through experimentation with iterative parametric operations such as knitting, weaving, and winding. This capacity that manifests itself is expressed with the term "material systems." Today's fabricated materials are subject to the same testing conducted by designers and researchers.

Knipper[20] argues that the creative way of thought has been upstaged by experimental design tested by materialization logic. Thus, it is crucial to comprehend these two terms which are the components of the material, design, and fabrication:

- Material design is defined as comprehending the intrinsic characteristics and structural behavior of the material and benefiting from these features in the design process.

- Materiality is defined as the digital process of materialization that adds to new sorts of digital tectonics with the help of digital fabrication processes, robotic technologies [Figure 10].[21]

With the help of digital technologies, information processes, material design, and production techniques combining design and fabrication, digital tectonics has become one of the stimulating concepts in parametric design. By intertwining design and production processes, the conventional order of tectonic processes in architecture alter from form-structure-material to material-structure-form, structure-material-form…etc. This diversification of order has changed the traditional model of design thinking.

Materials behave according to their molecular structure in the face of environmental factors such as heat, humidity, and pressure [Figures 11-13].[22] Metals have isotopic structures formed by orderly bonds of uniform atoms. Wood is a molecular, heterogeneous, and anisotropic material.[23] It exhibits different behavior in different directions. Wood's diversity in construction has played an important role in studies regarding experimental form production.

Conveying a certain architectural thought is possible through the form given to building materials through technical possibilities. Thinking together with the material design is an effective factor in the emergence of the product.[24] Just as Frank Lloyd Wright emphasized in the early 20$^{th}$ century, "A design suited for one material may not be suitable for another," the process of materials and forms interacting with each other is one that still continues today. In the 1970s, Frank Gehry built his house in Santa Monica using materials such as wire mesh, corrugated sheet metal, and plywood. In 1992, they exhibited innovative material approaches using polycarbonate double- and multi-wall sheeting and neon tubes bought from the Rem Koolhaas local market for the Art Gallery in Rotterdam. This approach also brought on different concepts to material ways in new designs and material approaches.[25]

Nowadays, amorphous approaches in building structures have started taking on more of a shell-like appearance in formulating exterior surfaces. Surface designs with topological continuity allow for flexible and geometric


**Figure 9.** (a-c) Enneper surface, volatile matter project, New York[19]

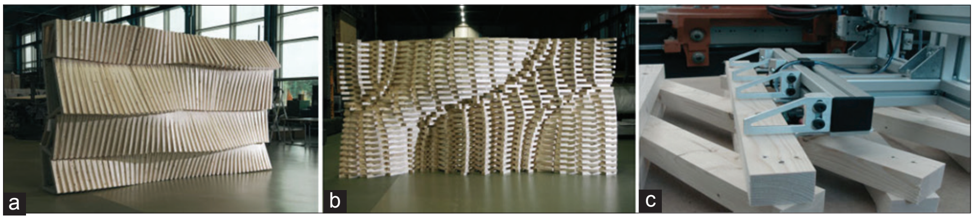



**Figure 10.** (a-c) Investigation of the architectonic and constructive potential of additive digital fabrication in timber construction[21]


**Figure 11.** (a-c) Fiber-C, glass fiber-reinforced concrete material, Bedford Square, London, United Kingdom, Zaha Hadid Architects, Synthesis Design + Architecture w/Nex Architecture, Adams Kara Taylor[26]

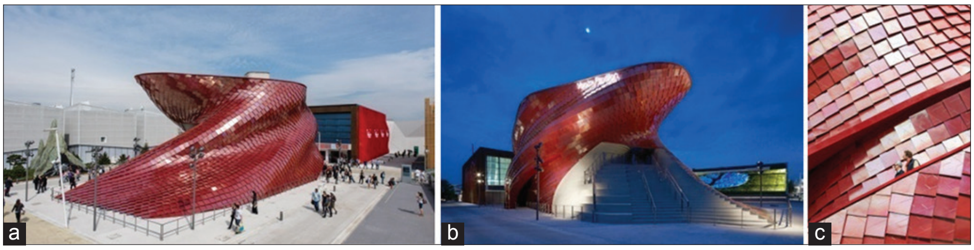


**Figure 12.** (a-c) Daniel Libeskind, 4000 shimmering ceramic tiles, handcrafted dragon, Daniel Libeskind, Milan Expo 2015[27]

**Figure 13.** (a-c) Curved aluminum structure, temporary pavilion to house multimedia installation, Burnham Pavilion, Zaha Hadid Architects in Chicago[28]

forms, bending surfaces, disassembly, and similar designs. This design approach has become easier to use with materials such as polymers, membranes, as well as conventional materials.

## 3 Wooden materials and the parametric design relationship

Since wood is a natural product, its dimension is limited in that its fibrous structural capacity to bear weight varies according to the fiber direction. Despite its widespread use, it had not been used in multi-storey and wide-span structures to the extent of reinforced concrete and steel structures commonly built after the industrial revolution.[29] In recent years, it has become a sought-after and preferred material as an eco-friendly natural material, does not leave waste, can pass through very large openings with new production techniques and can be used in multi-storey buildings. In this section, the relation between parametric design and wooden materials which can be used for the specimens taken up in the study is mentioned. In many aspects, wood is an advantageous material due to its natural structure, lightweight, high strength, non-waste to the environment, and its ability to be produced. It is environmentally sustainable and can be used outdoors.[30] In terms of usage, it is preferred because it is a warm looking material.

### 3.1. Wooden materials and their properties

Wood is a fibrous, heterogeneous, and anisotropic material. It is light and strong because it is fibrous. Since it is a natural material, its safety stresses are taken at low levels. When moisture is absorbed into the wood, its cellulose and bonds swell and shrink, whereas cracks and deformation are caused when moisture is lost. However, while artificially produced wood has improved these properties, it has also increased the range ofpossibilities.[23]

Depending on the wood texture, it is possible to change the size and thereby tensile properties of wooden parts affected by the growth rings [Figure 14]. The parallel and perpendicular pressure and tensile differences of natural wood fibers, as well as the size variation of the fibers according to the direction of formation, makes it difficult to use.

Whether as a solid or wood composite, the use of outer coating materials, such as MDF, chipboard, laminated, and wood plastic has been on the steady rise. It is known that today's usage is widely used as a composite, while the massive state of small-sized materials continues to be used by exposing them to chemical conditioning.[32] Wood produced with today's technology is industrial products that feature stronger physical properties of many different types. Industrial wood can be taken up as timber and structural composites. Products such as plywood and chipboard may be included in this class [Table 1].[33]

In today's wood technology, products generated by binding wood with water-resistant adhesives are called Structural Composite Lumber - SCL and can be assessed separately.[31] With the production of composite wood, materials of large size and high

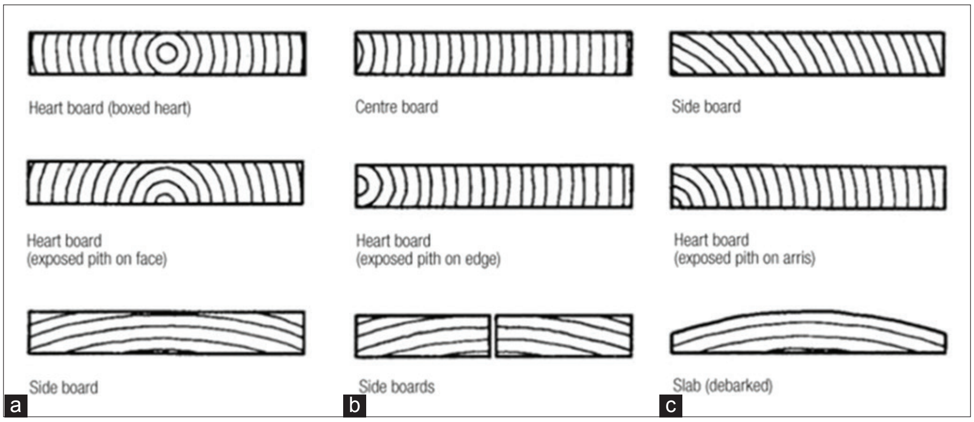



**Figure 14.** (a-c) Conversion options for boards[31]

**Table 1. Wood sheet products [25,31]**

<table>
<tr><td>Plywood</td><td colspan="2">It is obtained by peeling logs into thin sheets in special machines and gluing them together by placing the fibers of these sheets perpendicular to each other. It should be constructed from at least three layers. For panels with three or more single plates, the thickness of the inner layers should be 45% or more of the total thickness of the panel. Plywood is produced in different types, according to their utilization and type of wood used in the layers, the way the sheet surfaces are dressed, the way they are glued together and their production technique [Figure 15].</td></tr>
<tr><td>Chipboard</td><td colspan="2">This is the production of hard sheet wood featuring a relatively smooth surface by separating wood particles into certain small sizes then compress-heating them with adhesive. It is produced at various densities and hardnesses. This type of chipboard is durable, hard, and heavy. There are chipboards available for outdoor use, but most are only suitable for indoors. Laminated chipboard is used in the furniture sector.</td></tr>
<tr><td>OSB-Oriented strand board</td><td colspan="2">Weak, light, and fast growing tree species with slim circumferences are used in the production of OSB. Chips obtained from bark short logs are glued with the outer faces laid perpendicular to boost the resistance of the inner sections, then are hot-press treated. OSB board is used in furniture, concrete molds, wall paneling, etc.</td></tr>
<tr><td rowspan="2">Fiberboard</td><td rowspan="2">Fiberboard is produced by dressing the fibers of wood or similar fibrous plants with adhesives and additives. Tree species with long fibers are preferred.</td><td>MDF (Medium-Density Fiberboard) is medium-density fiberboard. The sheet surface is covered with special melamine-coated resin impregnated paper on a very smooth surface so that sheets of various designs and colors are obtained and used in many sectors of the furniture industry.</td></tr>
<tr><td>HDF (High-Density Fiberboard) is a harder and more dense material than MDF. Produced using wet and dry methods, it takes shape through the application of compressed heat in the wet method, whereby heat-dried adhesives are spread onto the fibers in the dry method.</td></tr>
</table>

durability can be obtained from small-sized, low-quality timber [Table 2].

Besides structural composites, wood and non-wood composite materials are also considered in the context of wood materials. Materials in this group are obtained using various binders to bind wood or similar fibrous materials. The material properties vary depending on the type and amount of binder used. This group also constitutes a rather wide product lineup. Considered amongst these are inorganic binding sheets and wood polymers. Gypsum, magnesium cement, and Portland cement are used as binding material in inorganic binders. Inorganic substance binding composites are resilient against harmful elements such as insects, fire, bacteria, and so on.

Wood fiber-reinforced thermoplastic composites are made by combining wood and similar plants together with thermoplastics along with polypropylene, polystyrene, vinyl, and low- and high-density polyethylene. There are two main methods in the production of thermoplastic composites. The first method is that woody materials serve as filler or reinforcing material inside the thermoplastic, and the second one has the thermoplastic serves as an adhesive for the woody material.

### 3.2 Wood in parametric design

Design criteria have also changed as wooden dimensions, which are defined as industrial products, exceed block wood dimensions. Innovative wood

**Table 2. Wooden composite products**[31,38]

| | |
|---|---|
| Glulam | Glulam is the oldest adhesive laminated wood product. Glued laminated timber is one of the most important semi-finished products among the SCLs. Production of glulam is cutting thin plates from solid wood and adding these plates side-by-side and one atop of another. They are comprised three or more layers, whereas the thickness of these elements should not exceed 50 mm. While the size of elements obtained from solid wood is limited, the production of larger-sized elements is possible by utilizing the lamination system. |
| Parallel strand lumber | This is a composite material obtained by the compressing strip chips obtained from the wood material under pressure. Coatings can now be used in production. It is obtained by bonding individual 3 mm thick coating strips with phenolic resin. A waterproof glue is applied, and it is pressed continuously in the pressing machine. The glue is hardened using microwave equipment. This timber can be used for long openings. It is more useful than solid timber as it has stronger properties. |
| (Ultralam)/laminated veneer lumber | This is achieved by gluing two or more wood coating layers, joining them, so the fibers are either parallel or perpendicular to each other. The fiber direction of the layers must be parallel for curved products to be manufactured. There are no length restrictions because laminated wood can be processed with cross fibers. For this reason, it is widely used in the building sector. Each board is comprised seven or more layers of wood, each 3 mm thick. Ultralam can be produced in plates and logs. It is a durable material from the standpoint of fire-resistance and load bearing. It can be used as various building elements [Figure 16]. |
| OSL | OSL is produced by binding long fibers to one other using compressed heat. It has a high load bearing capacity and reaches sizes not possible with natural wood. It has a wide usage area. Produced from 300 mm long chips, OSL chips are lined up unidirectionally at a uniform density and quickly pressed. |
| LSL | Small and curved wood types of many species can be used. LSL is a wood-based composite produced from 0.8 mm × 25 mm × 300 mm waterproof adhesive and wood strips. Two types of LSL are produced. Fibers can be used either unidirectional or bidirectional. It is suitable for use in beams, thresholds, columns, etc. |
| CLT | Cross-laminated lumber is obtained by the cross-lamination of small pieces about 20–60 mm thick. CLT has become an engineering product over the past 20 years. First used as a roofing element, it has since expanded to become a building system in the construction sector. While natural solid wood is limited in spacing and generating floor height, CLT has greatly expanded these limitations. The introduction of CLT in production has facilitated new ways of high-durability connections and digital production wood [Figure 16]. |

OSL: Oriented strand lumber, LSL: Laminated strand lumber, CLT: Cross-laminated timber

has been used in different dimensions and forms as parametric design possibilities have developed [Figure 17].

Wooden materials have a rather wide range of usage in parametric design due to features such as weaving, bending, and folding [Figures 18-20].[42,43] Elements that make up the design can be positioned in different shapes according to wood's bending feature. New wood-based materials (liquefied wood, modified wood, and densified wood) processing technologies along with the new possibilities for depicting and calculating support.[44]

### *3.2.1 Weaving*

The fundamental principle of weaving in timber construction is translated into the convergence of two elements: Glulam beams and strips of plywood. Weaving utilizes the bending ability of timber and involves the laying of intersecting, flexible, linear members to create a form that may be a flat sheet, or a uni- or bi-curved surface.[42]

### *3.2.2 Bending*

Wood is an extremely elastic material and easy to bend thanks to its natural fiber structure. This property can be utilized in form generation and construction [Figure 21]. Timber rib shells take their cue from the elastic qualities of wood. They build upon a grid of ribs crossing in space, with each rib made up of curved or screwed laminated boards.[42] Bending structures develop bending stresses essentially under the influence of external loads. Shear stresses associated with changes in bending moments must also be considered in their designs.

### *3.2.3 Folding*

The folding technique is one of the strongest and most common techniques to transform a 2D flat surface into a 3D element to provide geometric structural stability.[47,48] While creating new designs with folding, the unique character of the material is protected. While traditional timber-frame structures use timber panels only for cladding and cross-bracing of beams, new typologies such as timber folded plates use plate-assemblies as support structures [Figures 22 and 23].

## 4 Analysis of seating elements and pavilions

Deciding on the necessity of function-urban furniture for the considered situation; positioning

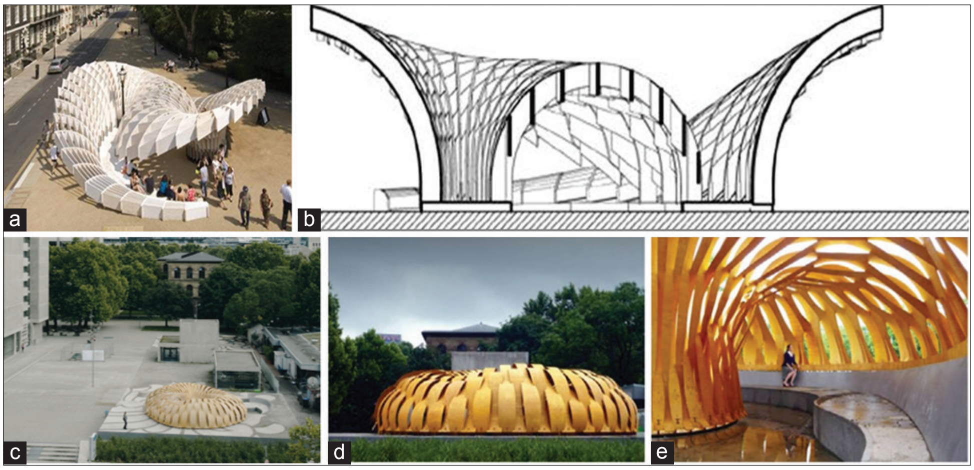


**Figure 15.** (a-e) Floor plan and section, made by plywood panels pavilions: Swoosh pavilion, Bedford Square, London, Valeria García Abarca, Charles Walker (professor), and Martin Self (professor, 154m$^2$);[34] General, exterior and interior structure, ICD/ITKE Research Pavilion 2010, Inst. for Computational Design (Prof. A. Menges), Inst. of Building Structures, and Structural Design (Prof. J. Knippers)[35-37]

**Figure 16.** (a-c) Compressed laminated bamboo, Forest Park Pavilion, 2007, St. Louis, Missouri, USA[39]

**Figure 17.** (a-c) The timber lattice system, Metropol Parasol Seville, Spain 2011 Jürgen Mayer H., 3400 individual wooden elements, 28.50 meters, concrete, timber and steel tree-shaped shading structure, high representation of free-form, prefabricated and assembled on-site, the freedom in making the node, or manufacturing the wood element[40,41]

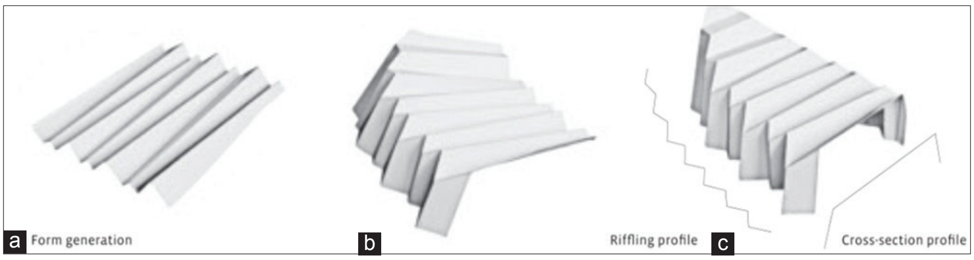
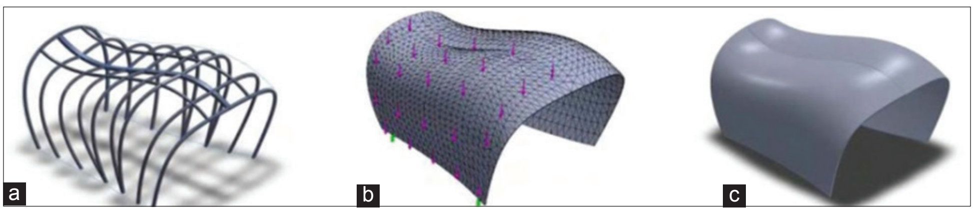



**Figure 18.** Tectonics of timber architecture in the digital age (folding, bending, and weaving)[42]



**Figures 19.** The tectonics of timber architecture as reflected in its production conditions[44]

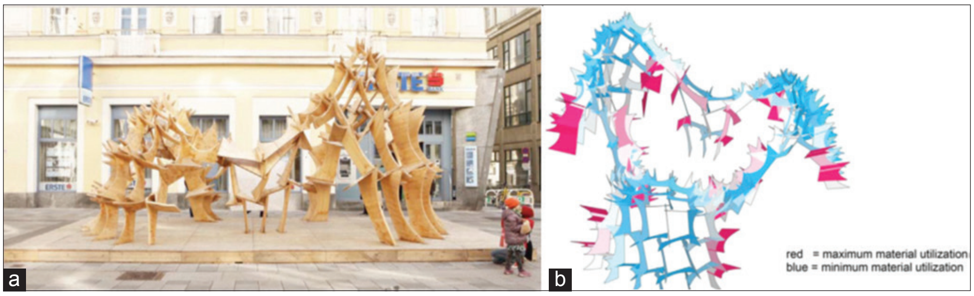



**Figure 20.** (a and b) Timber and polymer concrete, DigDesFab15 research pavilion, structural analysis in Karamba[45]

**Figure 21.** (a-c) Bending structures, ICD/ITKE Research Pavilion 2015–2016: Interactive Panorama by Heiko Stachel[46]

**Figure 22. (a-c)** Origami pavilion, Tal Friedman, aluminum material[49]

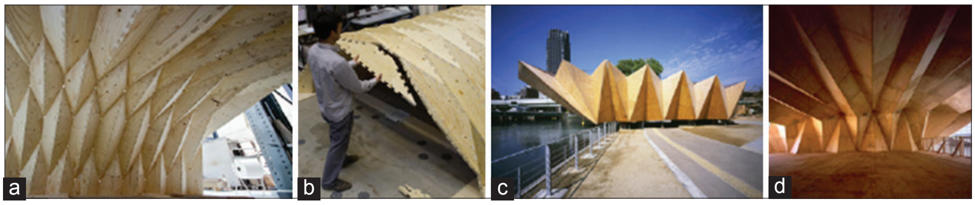


**Figure 23.** (a-d) Interlocking folded plate structure (left) and the temporary pavilion (right)[50]

and placement - finding the right spot; shape and appearance - ensuring continuity in the design of individual elements, or at least in the design itself; and durability and cost are the general principles in the selection and positioning of furniture.[51] In designing furniture, it is important to consider the user's physical, social, and utilization convenience. Material choices may vary depending on the design concept. It will be important that the materials used are outdoors, vandalism, and oxidation resilient. Wooden material can be considered as the most comfortable and durable material due to its flexibility and non-conveyance of heat and cold. Form and Formation, Structure and Materiality, which are thought to be effective in the parametric design of seating elements and pavilions in this chapter of the study, have been analyzed in selected specimens.

### 4.1 Urban adapter

2009, Hong Kong Bienali, Rocker Lange Architects

- Parametric Patterns: Repetition/force field
- Formation: Geometrical formation
- Structure: Self-sustaining modules
- Material: Walnut veneer MDF
- Tectonic order: Form-structure-material.

Instead of presenting just a single static design by trying to comprehend the street furniture concept as a holistic design problem, this design proposal presents many variable solutions that meet various criteria. In essence, this model benefits from the area it is positioned in and the pertinent programmatic data in interacting with its surroundings. This way, the structure of the model envisioned ensures the opportunity for the production of many unique pieces of furniture based on environmental data. Thus, new benches can be created in numerous forms. The design proposed for the urban element tries holistically to understand the concept of urban furniture. Rather than present a single static design deemed appropriate for one spot, a variable solution to the proposed scheme with many variations suitable for many spots has been proposed. In this way, the model's structure has the capacity to produce a series of unique urban furniture. Together they form a new group of urban bench elements that can evolve infinitely. While staking out a function for the seating elements, designs featuring pragrammatic values such as recycling bins, flower beds, and billboards can be added [Figure 24].

Generated by bringing together pre-dressed and pre-cut wood elements, parameters were derived from the track placed over it to fit into its surroundings. The variation of the dimensions in the X- and/or Y-axis during the repetition of the basic element has been changed according to the distance of the point on the track to the center axis of the track. Consequently, the seating element harmonizes with its surroundings either by narrowing or widening, depending on the curvation or straightness of the track. The parts formed by taking cutaways in the computer environment over the mass form constitute the basic building blocks of the product. As with a grid system structure, the fasteners, which are perpendicular to the axis of the variable parts, are fixed at the ends. The application of these connections from different points provides different design alternatives. It consists of a situation similar to a change in a DNA chromosome sequence. Different parameters can be created, and alternative uses can be had by changing the connection points.

### 4.2 Polymorphic bench

2011, New York, USA, GSAPP Architects

- Parametric Patterns: Repetition
- Formation: Kinetic formation
- Structure: Self-sustaining kinetic modules
- Material: Plywood
- Tectonic Order: Structure-Form-Material.

The basic elements that comprise the Polymorphic Bench were pre-engineered and created independently from the environment which it was to be installed. Elements cannot derive parameters from the track found over the Polymorphic Bench. Moreover, there is no apparent dimensional relationship between the track and elements. Designed for two-way utilization, this seating space provides rotational momentum on top of a backbone that sits on the floor. In this way, there is an unintended interaction between people who are sitting backward, making it easier for people to socialize.

Inspired by the see-saw, the Polymorphic Bench is comprised 119 parts connected to each other by a movable double-sided pivot and bolt system. There are two connections that allow the bench to maintain equilibrium. The first is a sliding bolt that controls displacement and acts as a limiter between the sections,

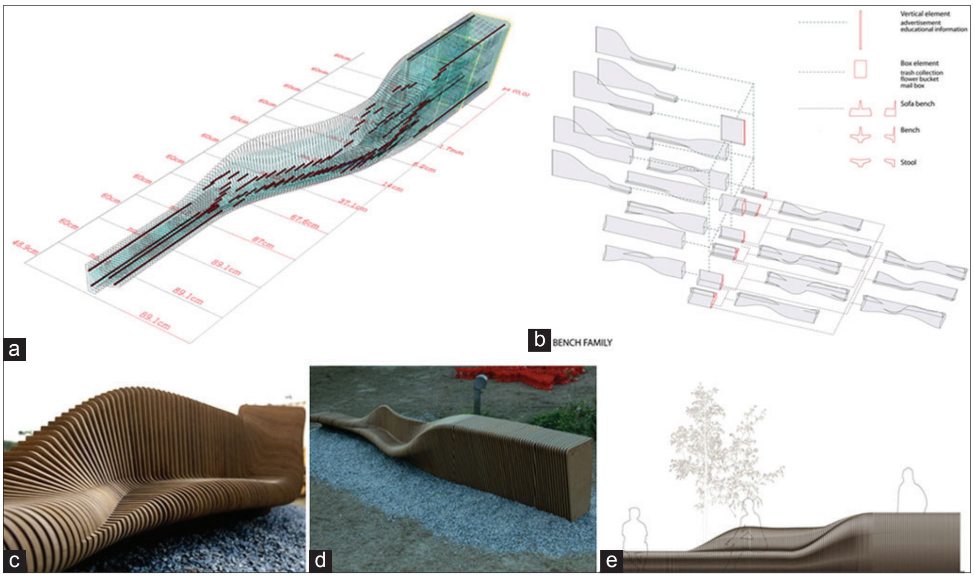



**Figure 24.** (a-e) Urban adapter[52]

while the second is a rubber band connection that lets the bench swing in motion [Figure 25]. A series of internal notches linked with rubber bands and reinforced with couplings over central pivot rods allow for lateral movement and provide safety during movement. The two simple connections not only ensure that the bench remains balanced but also ensure the movement of every section by applying pressure. One of the connections is a sliding bolt which limits movement between the sections and controls displacement, allowing it to move from adjacent sections. The second is a typical rubber band that gives the bench its springy quality while ensuring lateral stability of the installation as a whole.

### 4.3 Wood and concrete bench

2012, Rome, Italy, Sarah Gluck, Robyne Kassen, Simone Zbudil Bonatti

- Parametric Patterns: Force fields
- Formation: Geometrical formation
- Structure: Self-sustaining modules
- Material: Plywood, concrete, and rubber
- Tectonic Order: Form-Structure-Material.

At 40 m long, this is an ivy and water sprayer system that provides shade and coolness during sunny hours and ground LED illumination at night. The effort to promoting a wider community feeling and integrate health care into design again has been the main theme. Its goal is to get people to do meditation and body exercises with ergonomics suitable for body articulations. The ergonomic bench has been designed by taking into account criteria such as activating, strengthening, cleansing, and balancing the body with the mind and various body positions. Throughout the installation, there are a series of QR code apps visitors activate with their cell phones to get information about how these various movements are performed [Figure 26].

### 4.4 Parked bench

2015, London, England, Daniel Wiltshire, Frances McGeown - WMB Studio

- Parametric patterns: Repetition
- Formation: Geometrical formation
- Structure: Self-sustaining modules
- Material: Solid wood, red lacquer paint over MDF, and Galvanized steel
- Tectonic order: Form-Structure-Material.

The sculpted bench, designed at the distance of a two-car parking lot, functions as a vehicle-pedestrian road separation zone with planters at its end, while it also functions as an air cleaner [Figure 27]. It garners attention with a series of intertwining zigzags and glamorous colors. The various distances to the sidewalk meet the space needs such as people's bags, baby buggies and do not constitute a hindrance to people using the sidewalk.

The change of the size of the vertical and horizontal parts according to the direction of movement reinforces the work's dynamic structure. Height and width parameters are derived from the curved track lined up over the elements. The (x and y) points the horizontal elements are sitting on are found on top of the spline track drawn in the ground. The height of the vertical elements is related to the distance which is the spline track stop line of the point over which the element is situated. The further away the dot is from the line, the lower the height of the vertical element will be.

Solid wood is used in the lower parts of the project, and bright red painted material is used over the wood plate in the upper seating and leaning part. Various plant species were used in the zigzag sections of the bench. The vertical

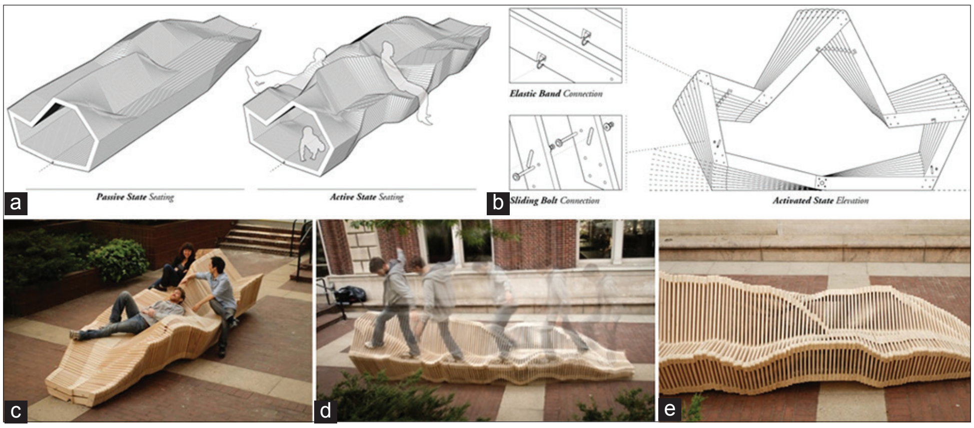



**Figure 25.** (a-e) Polymorphic bench[53]

**Figure 26.** (a-e) Wood and concrete bench[54]

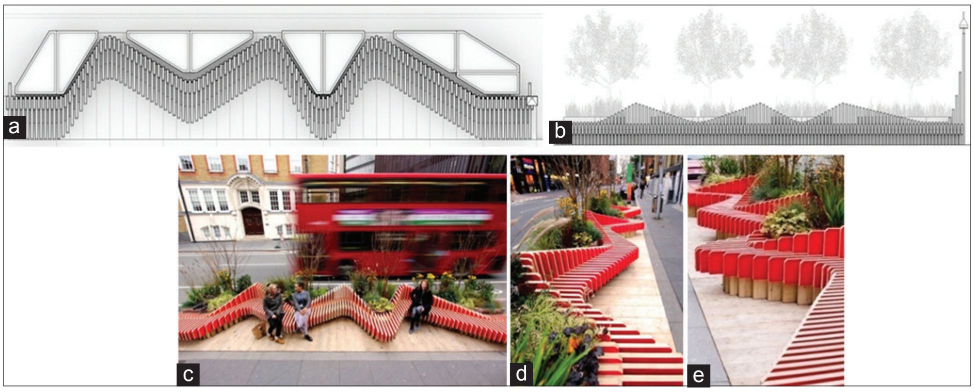


**Figure 27.** (a-e) Parked bench[55]

edges of the plates of this low-cost project were painted red to remotely check parking. These red plates increase the visual effect by contrasting with the green plants.

### 4.5 Zighizaghi jardin-multissensorial-na-italia-combina-natureza-e-musica

- 2016, Favara, Italy, OFL Architecture, Francesc o Lipari and Giuseppe Conti
- Parametric patterns: Tiling
- Formation: Modular formation
- Structure: Self-sustaining modules
- Material: Plywood and okume solid wood
- Tectonic order: Material-structure-form.

Comprised hexagonal forms similar to honeycombs, this project consist of two levels; horizontal (flooring and seating) and vertical (illumination systems). The horizontal level is comprised wood phenol-coated plywood and solid wood elements, whereas the vertical level is comprised a red-colored audio speaker system. The landscaping features Mediterranean plants selected according to the surrounding environment, as well as an automatic sprinkler system [Figure 28]. Transforming into an interactive character with a music system alongside plants and wood, the Zighizaghi turns music into a dynamic medium between nature and visitors.


**Figure 28.** (a-d) Zighizaghi jardin-multissensorial-na-italia-combina-natureza-e-musica[56]

## 4.6 Forest pavilion

Tayvan, 2011, Eric Bunge, Mimi Hoang (Principals); Ammr Vandal (Project Architect), Julia Chapman, Tiago Barros, Jack Hudspith, Alana Flick

- Parametric Patterns: Repetition
- Formation: Geometrical formation
- Structure: Self-sustaining vaulted modules
- Material: Bamboo
- Tectonic order: Form-material-structure.

Considered an outdoor theater that underscores conservation, shade and seating functions, this pavilion was designed as a conscious effort to preserve the history and traditional backdrop of the Da Nong Da Fu Forest Park, which is under threat of encroaching development. It was designed for an art festival to raise awareness to preserve and protect the nearby growth forest. In addition to festival opening and closing ceremonies, it is used as an outdoor theater. Moreover, thanks to the shade it generates, it has become an installation where people enter and rest. Theoretically speaking, the use of a single geometry allows infinite configurations using parabolic curved forms of freshly cut bamboo. The circular gathering area is comprised 11 vaulted parabolic bamboo arches displayed in two rings. The design of this structure is inspired from a tree's growth rings [Figure 29]. Covering 300 m$^2$, its arches reach a height of 6.7 m and are positioned over an area spanning 18 meters in circumference.

## 4.7 Crater lake

2011, Kobe, Japan 24° Studio

- Parametric Patterns: Subdivision/force field
- Formation: Geometrical formation
- Structure: Parameterized wooden frames
- Material: Solid wood
- Tectonic order: Form-structure-material
- Temporary
- Area: 80 m$^2$.

This pavilion was designed to diminish the negative psychological effects felt by local people after the Kobe Earthquake, to get people to socialize and to take advantage of the crater lake scenery. It was designed with wood covering elements over wooden studs at angles forming a circle from a single center. In constructing the piece, the circular design was divided into 20 radial parts which were preassembled before the installation. 30 mm × 60 mm treated cedar wood comprise the installation surface while 2 × 4 studs were used to create the structural armature beneath [Figure 30]. Designed to increase people's engagement, the pavilion has become a meeting spot with both lounging and seating facilities. It was created using solid pieces in linear structures at different angles, without implementing any wood evaporation, bending, or digital production methods. The hollow form in the center provides both solar and wind protection.

## 4.8 Mind-bending contemplay

2012, Montreal, Mc Gill University architecture students

- Parametric patterns: Repetition
- Formation: Geometrical formation
- Structure: Parameterized diagrid steel frames
- Material: Lamine plywood and steel
- Tectonic order: Form-structure-material.

While the design forms a perpetual spiral within itself, the pavilion presents different vistas as the surface


**Figure 29.** (a-d) Forest pavilion[57]

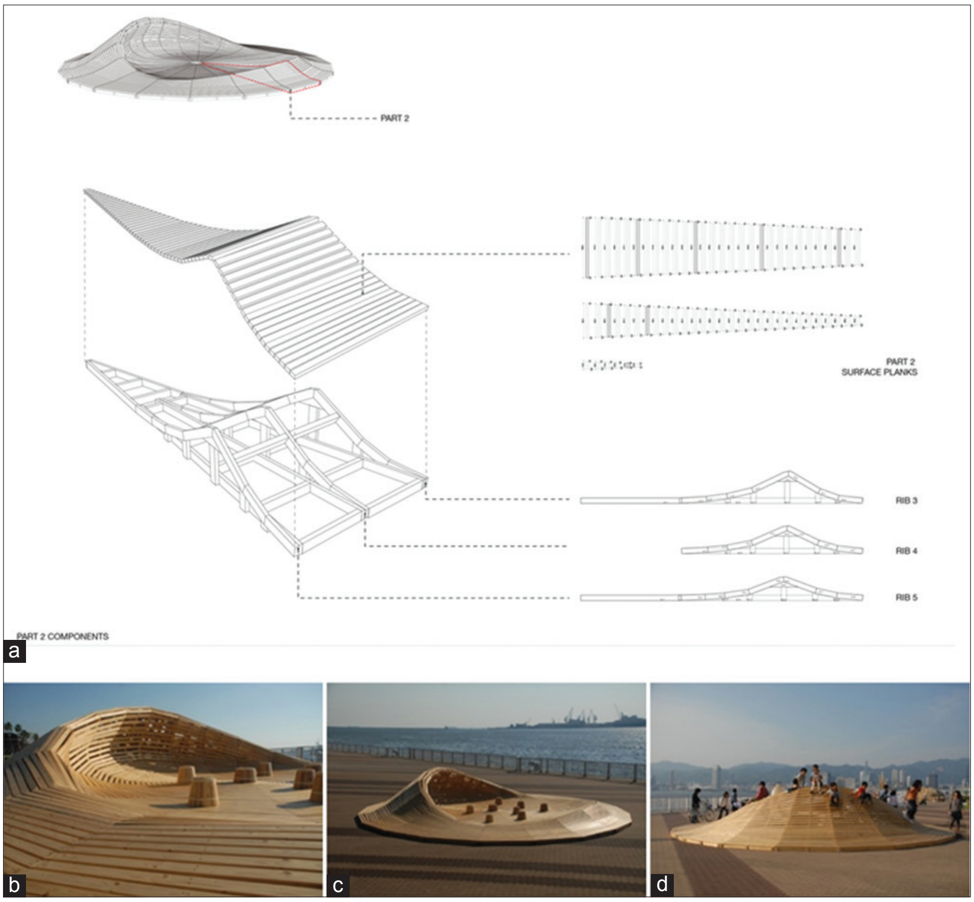



**Figure 30.** (a-d) Crater lake[58]

twists around [Figure 31]. The pavilion is composed of a hybrid lightweight framework, laminated plywood ribs and steel pipes covered with curved plywood strips. An intrinsically warped, self-attached space frame provides a powerful but flexible configuration that can solve complex geometry without entering the optical effect of the intended pavilion. The effect is created by two distinct coating layers that define the volume envelope of the Mobius strip. As you approach the pavilion, your eyes adjust to the dizzying effect as the inner space emerges. The esthetics of the structure is transformed into thoughts as it is embraced by a wall that transforms into a canopy.

### 4.9 Identity pavilion

2014, Plaça Nova, Barcelona, Spain, Liu Xiaodu, and Meng Yan

- Parametric patterns: Repetition
- Formation: Geometrical formation
- Structure: Self-sustaining space frame
- Material: Bamboo
- Tectonic order: Form-material-structure.

Designed to represent the Catalan identity, the pavilion is shaped by the abstraction of the Catalan clay vault, underscoring the evolution of the form from the original Roman arch [Figure 32]. It was designed to be dismantled after the festival, the assembly and disassembly stages were designed to be quite simple.

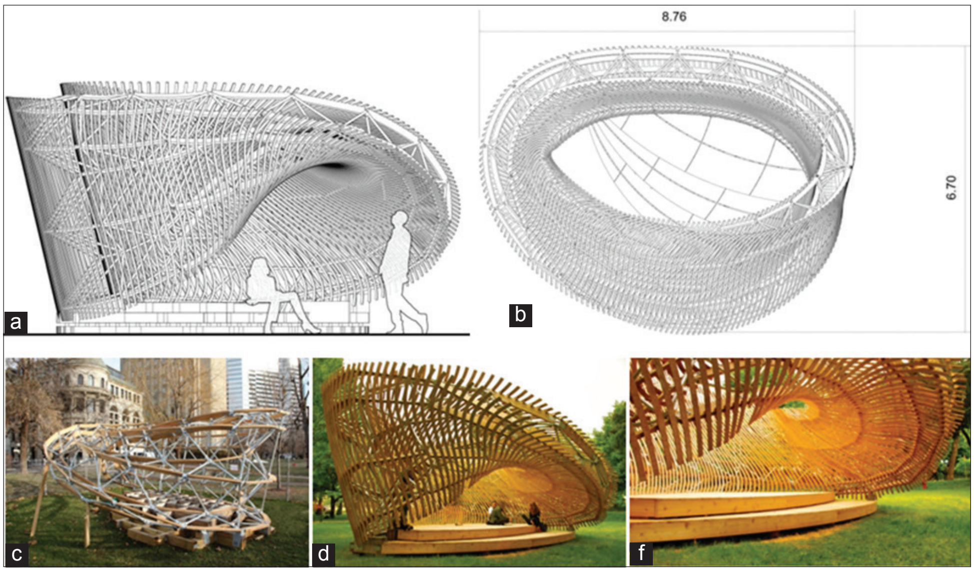



**Figure 31.** (a-f) Mind-Bending contemplay[59]

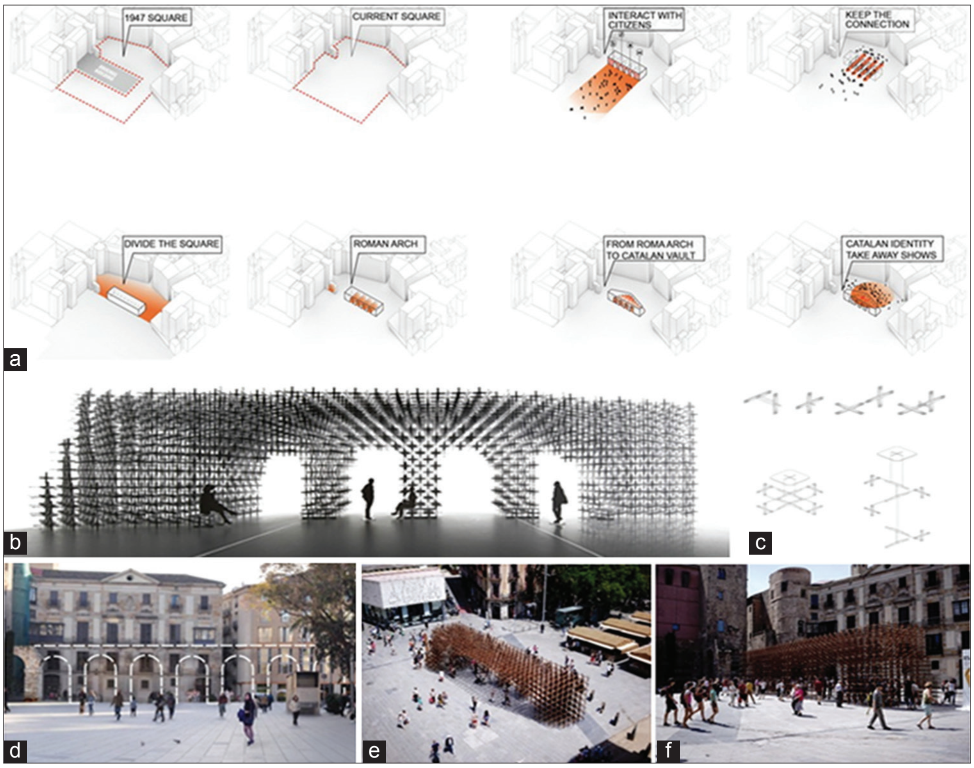



**Figure 32.** (a-f) Identity pavilion[60]

Straight bamboo rods reach the belt structure as a result of numerous connections at 90° angles to each other.

### 4.10 Street library

2017, Bulgaria, downtown studio

- Parametric patterns: Repetition
- Formation: Geometrical formation
- Structure: Self-sustaining wooden beams
- Material: Glulam
- Tectonic order: Form-structure-material.

It was created by rotating a curved beam element around a single angle and connecting these beams to each other with horizontal spacers. As a public resting area with the purpose of encouraging book sharing and reading, this pavilion is the first street library in Varna, Bulgaria. The main reason why the library layout resembles a seashell is because Varna is a coastal city and is often called "the maritime capital of Bulgaria." Constructed with 240 cm×250 cm×125 cm wooden blocks using CNC machines, the full capacity of the street library is 1500 books [Figure 33].

First, a computer-designed 3-D grid system of library's horizontal and vertical cutaways was generated. >20 variations of the same structure were tested to obtain optimum static and durability values. The various usages of the library sections were achieved through different parametric designs. The figure has a cutaway section obtained by joining two hoops with a drawn tangent. The radii of the hoops forming the cutaway, the distances of the hoops, the angle between the support shafts, and the number of support cutaways constitute the basic parameters. Structures of widely varying forms and sizes can be obtained merely by altering these five parameters.

## 5 Conclusion

From both functional and design values, benches and pavilions that function as seating, rest, and shady spots situated in areas such as squares and parks, and which can also be defined as urban interior venues, serve as complementary elements of services provided in the venue. The design and production of urban furniture continue to progress alongside advancing technology. The fact that computer technology is considered a part of the design process has expediting the calculation of costs, architectural processes, as well as presenting the opportunity for alternative drafts and suggestions.

In this study, criteria of form, structure and material usage of wooden parametric design products were conducted on specimens selected from different regions of the world [Table 3]; said specimens show that different variations of a single geometric form were used, there was no use of a common material when viewed from a material aspect, and that various materials were used according to designer preferences. In addition to these, it was seen that complex and sloping surfaces, as well as sloping flat surfaces, were used in the analyzed specimens.

In general, while using a support structure and covering or dividing elements that envelop this building system, geometric and repetitive elements comprised the design form in the examples of wooden parametric designs that were examined, they often constituted the support structure and, in fact, the repetition of these elements

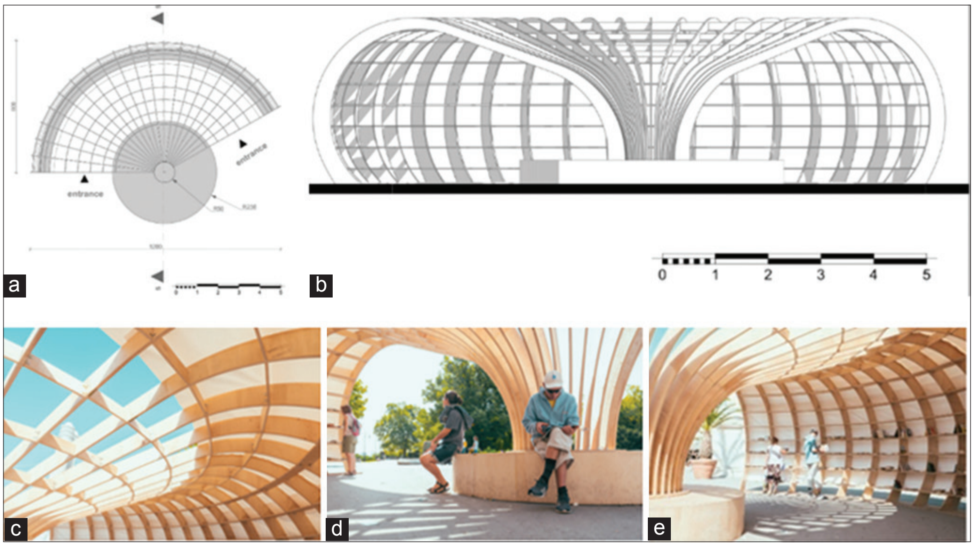



**Figure 33.** (a-e) Street library[61]

**Table 3. Evaluation of specimens in terms of parametric patterns, formations, structures, materials, and tectonic order**

| Evaluation Criteria | Parametric pattern | Formation | Structure | Material | Tectonic order |
|---|---|---|---|---|---|
| Seating elements | | | | | |
| Urban adapter | Repetition/Force field | Geometrical formation | Self-sustaining modules | Walnut veneer MDF | Form-structure-material |
| Polimorfik bench | Repetition | Kinetic formation | Self-sustaining kinetic modules | Plywood | Structure-form-material |
| Wood and concrete bench | Repetition | Geometrical formation | Self-sustaining modules | Plywood, concrete, rubber | Form-structure-material |
| Parked bench | Force fields | Geometrical formation | Self-sustaining modules | Solid wood, MDF, Galvanized Steel | Form-structure-material |
| Zighizaghi jardin | Tiling | Modular formation | Self-sustaining modules | Plywood, okume solid wood | Material-structure-form |
| Pavilion | | | | | |
| Forest pavilion | Repetition | Geometrical formation | Self-sustaining vaulted modules | Bamboo | Form-material-structure |
| Crater lake | Subdivision/force field | Geometrical formation | Parameterized wooden frames | Solid wood | Form-structure-material |
| Mind-bending contemplay | Repetition | Geometrical formation | Parameterized diagrid steel frames | Lamine plywood, steel | Form-structure-material |
| Identity pavilion | Repetition | Geometrical formation | Self-sustaining space frame | Bamboo | Form-material-Structure |
| Street library | Repetition | Geometrical formation | Self-sustaining wooden beams | Glulam | Form-structure-material |

and surfaces. There was no need for solutions such as individual support dividers or coating surfaces. The designs were realized holistically.

The generation and diversification of a single geometric form in the selected specimens are facilitated by the formation of different geometric surfaces; it is observed that the required criteria from the design, such as required flexibility, durability, and compatibility are considered in the analytic portion of the study. In viewing the specimens in the context of parametric patterns, it is seen that repetition is used extensively. In general, a total format is achieved by altering and/or transforming the determined modules. It is thought this situation is because the natural and processed properties of the wooden material intended for use have an impact on the initial design stage. In the specimens, it was observed that although the elements are designed with kinetic motion and to adapt according to the situation, they are generally geometrically shaped. This result is a comprehensible situation when ergonomics and anthropometry are factored into the seating elements. Then again, it is also possible to see this effect in the tectonic order section. Consequently, the priority form appears in the front plan in the tectonic order. In the pavilions, we see again that form is given priority in the tectonic order with factors such as cultural codes and the desired psychological perception to be created.

The natural and processed properties of wood are also effective in generating the structure. From a structural aspect, it is seen that self-supporting wooden modules are used effectively in design. In the specimens, it is observed that as a material, wood in both its natural and processed states, is found to be widely used in the designers' lineup. It is thought that rather than having wood appear in the forefront of any production technology, wood is kept in the forefront as a multi-material.

These days, as concepts of ecology and sustainability, are in the forefront, and design and production are supported by computer technology, the use of wood as a traditional material continues by changing, by transforming, and by expanding.

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