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## ENVIRONMENTAL IMPACT ON DIGITAL ERA BY ARCHITECTURAL PRODUCTION

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### Abstract

Current developments in architecture and construction demand innovation in design. Increasing demand and rapid production time require mass production. Digital fabrication with the combination of computed design and robotic manufacturing is a development in architectural design. Digital fabrication is also a product of modernization, which affects various components of the environment as well as social, economic, and cultural components. This study aims to provide an overview of the technology upgrade in the architectural and construction sectors that affect the environment, starting from the process of architectural design and construction products in the digital era up to the impact of these activities on the environment. The method used is descriptive research—by conducting observations from scientific evidence (literature studies) that support this research. First, the concept is described followed by the discussion of the production process of architectural design products in the current digital era and the influence of these activities on the environment, such as degradation on the aspects of the environment, economy, society, and culture. The results show that architectural production in the digital era has a negative impact on the environment due to architectural products created using digital fabrication systems as well as exploitation of natural resources, encouraging finance, and transportation of these products across borders. Social and cultural changes are degraded by local culture caused by cross-cultural, as well as a new phenomenon of universalization of culture (world culture) or what is now called the digital culture.

**Keywords:** environmental impact; digital era; architecture; production

### 1. Introduction

The rapid development of world economy has a significant influence on the development of technology. Humans are encouraged to develop technology that can facilitate work or other daily activities. For example, the existence of a computer makes things easier, including in the world of architecture. Currently, the drawing table is no longer used in the design process because there is already software, such as computer-aided design (CAD), SketchUp, often used in architecture. The increased use of computers by these architects affected the process of design review and model development for digital fabrication (Sass, 2006). This change will have an impact on one's way of life and on the health and the environment (Mardones, Iori, Becerra, Diaz, & Zagal, 2012). Digital fabrication is a developmental process of modernization products (Hague, Campbell, & Dickens, 2003). Digital fabrication has resulted in a different workflow, linking design and realization through standardization (Vazquez &

Jabi, 2015). Architecture and construction are currently undergoing developments in methods, design concepts, production, and construction. The development of digital technology has an enormous influence to the environment. Environmental responsibility as a result of growth mainly occurs in the architectural and construction sectors, employing 111 million workers worldwide (Ortiz, Castells, & Sonnemann, 2009). Besides, the construction industry is responsible for 40% of global energy consumption, 38% of greenhouse gas emissions, 12% of drinking water, and 40% of solid waste in the world (UNEP, 2012). Development has an impact on environmental degradation as a result of production. From an economic point of view, digital fabrication affects the increase of various sectors, especially in the manufacturing industry. Besides, social and cultural changes have a significant impact, especially in a universalized culture (Ricoeur, 1961).

## 2. Globalization

The term *globalization* was first put forward by Jaan Aart Scolthe in 1985 by dividing it into several scopes; the first being internationalization, which refers to the interdependence of relations between countries to meet their individual needs while maintaining their identity. Liberalization is transboundary between countries or crossing national borders that lead to increased migration and free trade. Universalization is described as the effect of globalization causing widespread dissemination of culture and locality of a country that has the basics for the formation of a universal culture. Westernization is defined as domination of Western culture on changes and loss of the value of other cultures.

The 21st century is the era of digital globalization, which can have an impact on the world, where the use of technology and information is not only a service for human needs but also a place to donate world markets. The present characteristics of globalization accompanied by rapid economic development have resulted in the emergence of environmental, economical, social, cultural problems, among others. The pace of globalization now has an impact on the degradation of the quality of the environment, the increase in the rate of poverty, and the reduction of local identity values. There is no limit to the values of cultural identity due to human mobility, free trade, rapid information, and easy (Salim, 2010). Crossing the boundaries of knowledge and culture that transpire has an influence on changes in social structure; this is called cross-cultural. Changes in social structures that transpire due to globalization result in loss of boundaries, cultural values, and local wisdom and the emergence of a universal cultural system or so-called world culture (Frampton, 1981).

Globalization gave birth to developments in various fields and was later supported by the development of science, technology, and information. Digital globalization is a new era in current global flows (Manyika et al., 2016). The digital age now allows the use of digital systems that dominate various aspects of activities and businesses, including education, economy, production, industry, manufacturing, among others. In the field of digital system, manufacturing is used as a tool to produce a product to improve quality and also increase the rate of production; this is so that the time used is more efficient and effective. Digitalization is a product of globalization that continues to develop with the development of science, which led to new innovations for human utilization and increased development of human resources, infrastructure, among others. Some of the negative effects of globalization include

changes in environmental, social, cultural, and other qualities that result in human consciousness and the emergence of movements to restore the environment to the uniqueness of locality and the culture of each country. Several studies have been carried out on digital production, especially on architectural production, which has resulted in a decrease in environmental quality due to exploitation of natural resources, energy use, and environmental testing. This paper aims to look at the impact of globalization on the production of digital architecture on the environment, including digital fabrication, a production technique for innovation and improving the quality of the products produced.

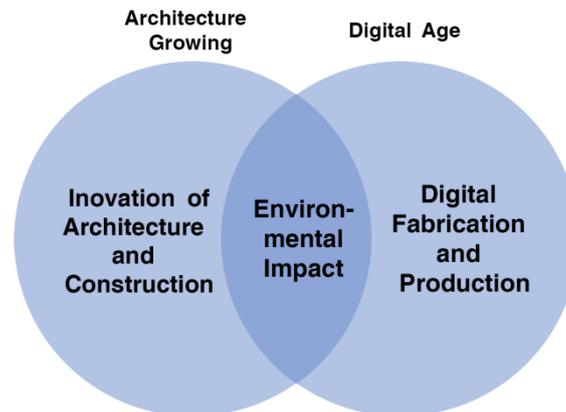


Figure 1. Diagram of environmental changes due to architectural production and construction in digital modernization.

The development of architecture in the digital era increases innovation in design techniques and production techniques (digital fabrication) as in Figure 1. This shows a diagram of environmental influences due to the phenomenon of architectural development in the digital era.

### 3. Architecture Growing to Digital Era

The development of architecture initially derived from human needs. Humans build shelter to protect themselves from both wild animals and weather conditions. Later on, the increasing number of people and the development of science prompted curiosity including in the field of architecture. There are various meanings of *construction* according to academics and practitioners. Architecture is a work of art of human imagination inspired by a scientific form of nature by building structured ideas to create a better life (Wright, 1930). Architectural design approach is a conventional method that is limited by tools and knowledge, experience, and environmental influences. The development of the world of architecture and construction in the digital era has had a huge impact on the approach of design methods, especially on the development process and results of product design. The production results affect the designing method and production techniques. Digital production that produces designs or products with the use of computerized systematics is called digital fabrication. Digital fabrication consists of two distinct sub-fields. According to Ryder, Ion, Green, Harrison, & Wood (2002), the first sub-field is fast in prototyping for the model-making process. The second sub-field is computer numerical control (CNC), which is the fabrication process for

building components (Iwamoto, 2004). According to McMahon & Browne (1998), CNC is a computer system that serves to control the function of a movement of a machine that uses a set of instruction codes. According to Zeid (1991), the use of CNC focuses only on the production of mass-manufactured products, such as aircraft and auto parts, but now CNC is also used for the production of products with small manufacturing. The production process begins with 2D or 3D descriptions as a virtual model in which some 3D descriptions start with digital fabrication in stable stocks carved with virtual model shapes (Sass, 2006).

### 3.1 Digital Fabrication as Output from Parametric Design in Architecture Term

In architectural practice, digital fabrication is also known as one of its parametric design methods or also called design generation and exploration (Oxman, 2006; Woodbury, 2010). There are six functions of parametric design that is the process of transplanting the idea of design to the parametric model, the rational design in order to be built, as the control of architectural form, as a tool to test the variation of design formed especially in exploration aspect and design optimization, as reference of automatic design and increase knowledge design from various fields of science (Hudson, 2010). Initially, the parametric model was used by Foster and Partner's conservation as the control and rationalization of the form to be built. The model is defined by computer programs that are based on geometric patterns that most designers programmatically design (Whitehead, 2003).

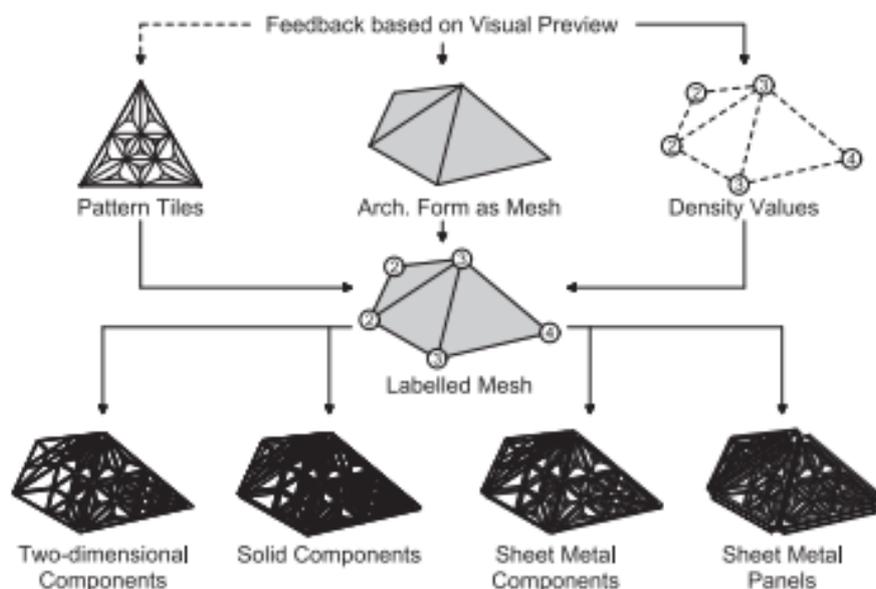


Figure 2. Parametric design model  
(Source: Wortmann & Tunçer, 2017)

Figure 2 shows the parametric design model that is designed using computer control with the parametric system method. The parametric design system is a new method in the world of architecture that is used in designing a model or form with geometric and complex pattern, which can only be done through a computer program. Some of the software used in architectural design is Rhinoceros, Grasshopper, and others.

### **3.2 Digital Fabrication as an Output of the Architectural Innovation Product**

In the digital era, the use of highly developed technology and information has resulted in increased production in several industrial fields, there are several construction innovations in the field of architecture as design solutions to existing problems. This aims to improve design innovation, aesthetics, comfort, and sustainability. Approaching architectural designs now refers to the ecological footprint; because the world is aware of the importance of the survival of humans and their environment, several world conferences have been held ([Copenhagen, 2009](#); [Kyoto Protocol, 1997](#); [Rio Declaration, 1992](#)) has put forward the concept of sustainable development which was first introduced by G. H Brundtland, which means that development is carried out efficiently and effectively without reducing the need for future generations. In the field of Green Architecture, Green Building, as a solution to various environmental issues, and becomes the main consideration in designing buildings ([Baubiologie, 1975](#); [UIA, 1993](#)). Then some architectural construction products are delivered by solar panels, shading walls, wind turbines, anti-radiation glass, and some fabricating materials, such as fiberglass, vinyl, aluminium, among others. Green Building materials produced by the construction industry are around 40% to 48% of the non-residential sector, which is an increase of 1.4% from 2005 ([GBC, 2016](#)). According environmental design approach how digital fabrication can be responsible with environment, while digital fabrication as a production technique to increase of production on large numbers in the current digital era, resulting in efficient, effective, and innovative production, especially as a forum for creativity in the field of architecture.

## **4. Production Process Architecture of Digital Fabrication**

The current fabrication process known as digital fabrication and world architectural practice have been progressing rapidly since two decades ago ([Wortmann & Tunçer, 2017](#)). Digital fabrication in the world of architecture is a process that has been planned, assessed, and optimized during the design phase ([Gershenfield, 2012](#)). Digital fabrication is also defined as a manufacturing technology that can produce new components or products ([Gibson, Rosen, & Stucker, 2010](#)). Also in the process is a direct product without using technologies, such as 3D printing and additive manufacture ([Holmström, Liotta, & Chauduri, 2017](#)). Two-dimensional digital fabrication consisting of various cutting technologies, such as plasma arc and a laser beam, is the most commonly used fabrication technique ([Kolarevic, 2001](#)). Contouring, triangulation, and unfolding are part of the 2D fabrication production strategy that involves the extraction of 2D complex compounds of the building form ([Kolarevic, 2001](#)).

### **4.1 Architecture Design**

Design in architecture is a strategy in problem solving that uses the ability of creativity, art, and science to obtain solutions ([Wardah & Khalil, 2016](#)). The design is a complex activity that produces various shapes from each different designer background ([Cavallin, 2009](#)). The purpose of architectural design as a primary course is to build the environment as well as a human with the environment ([Saghafi, Mozaffar, & Moosavi, 2015](#)).

In [Jones \(1970\)](#), design process does not represent the process of creating something but as a structured and relevant foundation of principle. There are three main structures in the design process:

- a. Collection of information, including how to organize, analyze, and how to relate to the design.
- b. Examining, intervention through the design with the process of intellectual ability, intuition, and based on the experience of the designer.
- c. The process of evaluation, namely by setting design decisions tailored to the context of the problem.

Developing of architectural design on the digital era today requires the existence of a fabrication production system through a parametric design system with 3D printing as a printing tool from a model that has been designed. The parametric design method is used by several world architecture consultants by using computer programs as development and exploration in their designs and works, and one example of ZHA Architect with the Guangzhou Opera House, London Aquatic Center, Heydar Aliyev Center, Wangjin SOHO, among others. This is used as an innovation enhancement design in architecture as well as the aesthetics of the forms produced.



Figure 3. Model and architectural design work using parametric design method

#### 4.2 Parametric Design Implementation

The parametric design model is a model employing systems that utilize computer software (Grasshopper, Rhinoceros, etc.) to realize shapes, models, and designs with certain complexity. Nowadays, the production of parametric models is very difficult to implement using conventional methods. Using 3D printing is an innovation that can be used in the modern digital era. Zaha Hadid Architects has tried to realize a parametric model of design in the Mexpheus hotel building in Macau. The model is a parametric model with building structures in the facade of the building (Figure 4).



Figure 4. Parametric structure model that become façade of Morpheus Hotel  
(Source: [Wortmann & Tunçer, 2017](#))

Then to realize the parametric model, several contractors in the construction sector were forced to work on the project with a number of strategies. The details on the design are used as the starting point in the software used to design the building model, then the material process is made through a fabrication process with 3D printing so as to produce materials that are similar to the computer-designed model.

Digital fabrication practice is now using direct digital manufacturing (DDM) ([Holmström et al., 2017](#)). DDM is a concept development that is more than 3D printing with swift production ([ASTM International, 2012](#); [Hopkinson & Dickens, 2001](#)).

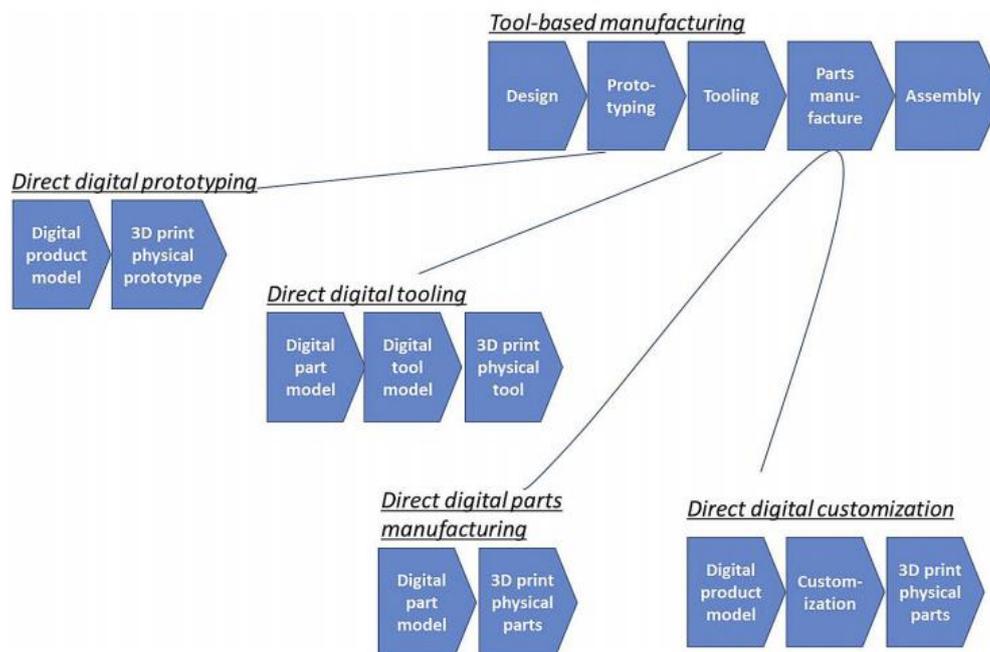


Figure 5. Steps and practical process of digital fabrication  
(Source: [Holmström et al., 2017](#))

Figure 5 shows the stages and processes of digital fabrication practice with the development of a concept called *direct digital manufacturing* (DDM). Some of the production stages depend on the type of product with different ways of making the product. Prototyping is by duplicating a large number of products from the 3D digital model design. Tooling is producing a tool needed directly from the part of a model. Manufacturing is producing small parts with complexity. Complicated customization of the production process due to customer's demand after the product is printed using 3D digital printing until the assembly process. More importantly, the development of the idea of production allows us to study its application (Holmström et al., 2017).

### 4.3 Direct Digital Prototyping

In manufacturing, direct digital prototyping has long been used for time efficiency and speed of production (Onuh & Yusuf, 1999). The product results are the prototype and 3D digital model (Drizo & Pegna, 2006; Eyers & Potter, 2015). In addition to accelerating production, the concept also increases resource use as well as production and development. The goal is to enhance the development of models and designs for architects, designers, and engineers (Holmström et al., 2017).

Direct digital tooling is the process of producing the necessary tools in the manufacture of a model (Holmström et al., 2017). The results of 3D digital models at this stage are used as a tool to create the final model (Altan, Lilly, & Yen, 2001). The primary function of this phase of modelling is in the process which can change the design of an end product so that the design changes from production can be faster (Holmström et al., 2017). It is beneficial to minimize the use of materials that can produce large amounts of waste material (Chen et al., 2015; Khajavi, Partanen, & Holmstrom, 2014).

Direct digital parts manufacturing was developed to produce small parts of the design that have involved geometric complexities generated from demand with a wide variety of designs. This makes it possible to increase the range of product variety levels without the high cost (Holmström et al., 2017), supporting and enhance quality of product.

Direct digital parts customization is a production technique adjusted according to customer's demand (Chen et al., 2015). The use of configurator and sometimes concurrent 3D scanners can produce directly a custom 3D model/product (Holmström et al., 2017). Customization is a methods of production to support creativity of design production and accommodate people desires also increase trading of product.

## 5. Environmental Impact on Digital Fabrication

Digital fabrication is an idea developed from various regional improvements resulting in a wider production of trans-boundaries in each region. Digital fabrication has a massive impact on the economy, society and culture, and also the environment.

### 5.1 Environmental Changes

Agusti Juan and Guillaume Habert compared the design of digital fabrication with the conventional construction in their study. The comparison is focused on the production and operation of two types of facades on one of the radars in Texas (USA) using Life Cycle Assessment (LCA). As a result, the facade with self-shading wall, which is a digital

fabrication product, resulted in a more significant impact on the environment as compared to conventional facades with the same work and structural and thermal.

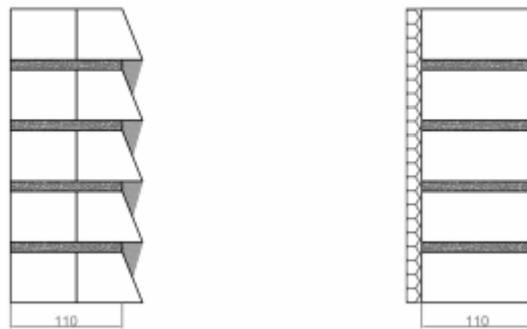


Figure 6. Self-shading and brick wall  
(Source: Juan & Habert, 2016)

Figure 6 shows the fabrication design of two types of production walls (self-shading wall and brick wall). Both production walls are compared with the results of fabrication.

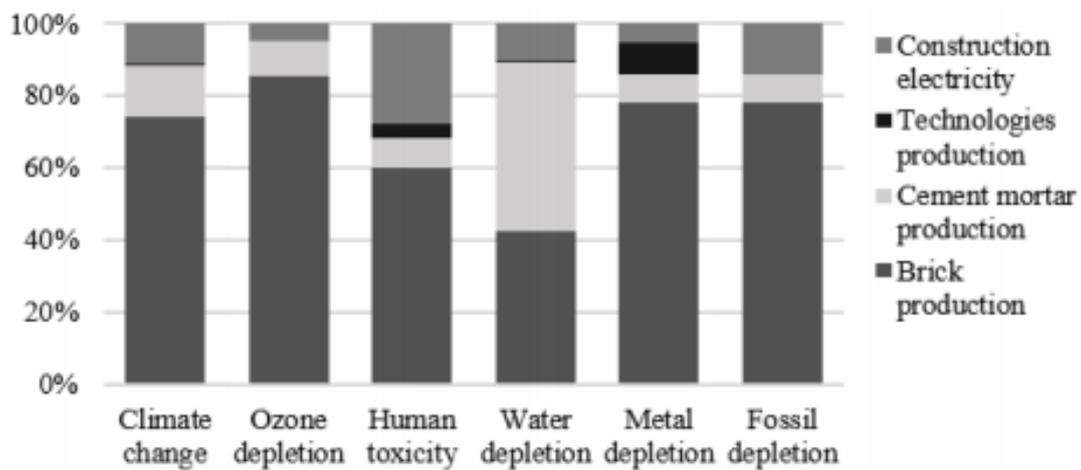


Figure 7. Stages of self-shading wall production to the environmental impact.  
(Source: Juan & Habert, 2016)

Figure 7 shows the stages in self-shading wall production (construction electricity, production technology, cement mortar production, and brick production) tested with six variables of environmental impact (climate change, ozone depletion, human toxicity, water depletion, metal depletion, and fossil depletion).

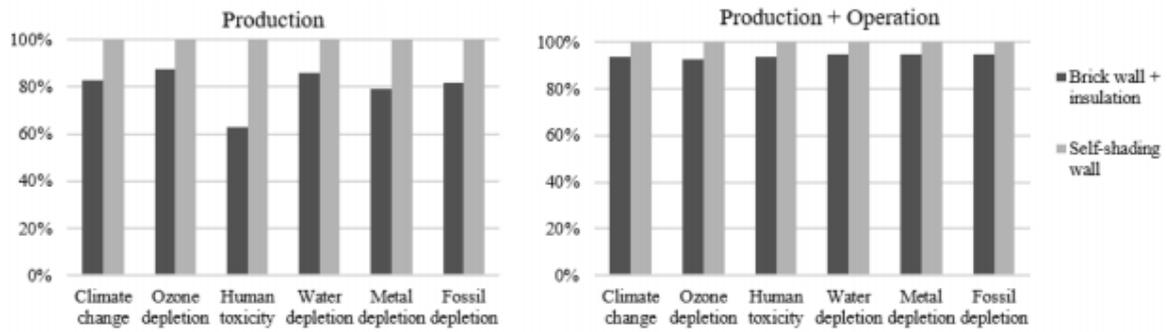


Figure 8. (a) Comparison of environmental impacts from the brick wall and self-shading wall production. (b) Comparison of the environmental effects between the creation and operation of the brick wall and self-shading wall  
(Source: [Juan & Habert, 2016](#))

Figure 8 shows that, with a six-variable set (climate change, ozone depletion, human toxicity, water depletion, metal depletion, and fossil depletion), digital fabrication has a negative impact on the environment as compared to conventional design products. Nowadays, architectural digital production delivered new innovation of design, model, and shape; digital fabrication as a service to increase a large number of productions rapidly but environmental concern must be considered.

## 5.2 Economical Changes

A new era in globalization has caused trade borderless between the countries, while world demand greatly increased. This was due to digital technology and information changing the movement of businesses around the world into cross-border countries and participation throughout the world ([MCKensey Global Institute, 2016](#)). Large multinationals includes a new market with a global scale and strategies, new products and assets, and organizations. The second startups are small and medium enterprises; the digital platform is used to get customers and suppliers across national borders. Third startups of technology and information-based companies that will dominate the global scale, then the fourth are individual companies, who are paving a new way of trading in the digital era where everyone can establish a company or sell individually and also sell products at home without having a physical shop.



Figure 9. Changes in data flows between 1980 and 2014  
(Source: MCKensey Global Institue, 2016)

Changes in data flows that occurred from 1980 to 2014 (digital era) resulted in the change of a new era in the world of business and trade throughout the world (Figure 9). The new era of digital globalization is a data stream that has risen 45 times as compared to previous global flows. Increased use of the digital platform shows general or global demand, it paves the way for creating businesses in the digital platform, such as online shops.

Scientific and technological advances influence various economic factors. Modern industrial sector requires innovation, including a new product and a new process of production. Traditional industrial production systems cannot facilitate the market demand of a transboundary industry, with increasing demand with of large quantities of product rapidly. Technology and digital platform should be used to facilitate manufacturing production and in response to challenges on digital era.

Digital fabrication is a development of innovation in the digital era with technological support and increasing needs and production of goods. One of the impacts caused by the development of digital fabrication was triggered by efforts to improve the economy of each country. The development of the digital age information is a great opportunity for each industry to increase the commercialization of industrial products. Internet development facilitates the commercialization of products rapidly and increase demand on a transboundary basis. Digital fabrication (3D printing, laser cutter, and computer numeric control or CNC) is used to facilitate the production of mass quantities of goods rapidly. The production of 3D printing and laser cutter is done through CNC programming so the products produced are according to the computer-designed models.

The impact of economic changes caused by digital-fabrication production techniques greatly influences economic improvement (Thiesse et al., 2015) then widely developed as a new revolution (Gershenfeld, 2012). In 2013, the digital fabrication market earned up to \$3.07 billion worldwide, with an annual growth of 34.9%. Then, in 2021, the revenue is estimated to reach \$10.08 billion (Wohlers & Caffrey, 2013). Digital fabrication offers flexibility, which relates to manufacturing processes' ability to produce quickly with ever-changing demand besides efficiency regarding shorter production times with more optimal costs. Technology plays a big role in the process of digital fabrication, with its high level of flexibility and its tools that are easy-to-use and produce quickly, also called rapid tooling,

then using technology that can replace human intervention. Also, there is a difference between prices from traditional mass production and mass production in the current customization era (Thiesse et al., 2015).

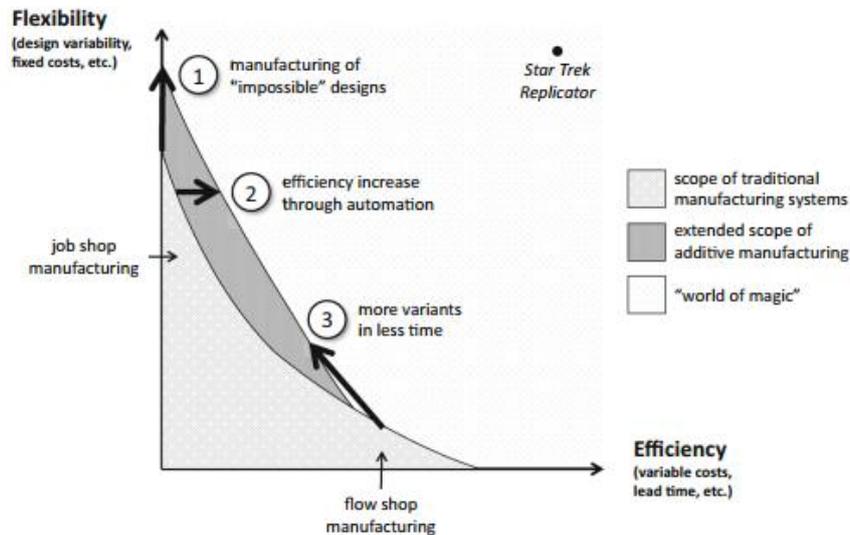


Figure 10. Effect of 3D printing to manufacturing system changes  
(Source: Thiesse et al., 2015)

Figure 10 shows the effects of 3D printing in the manufacturing system. Traditional manufacturing systems use conventional systems, then Additive Manufacture/Digital Fabrication and World Magic. World Magic is a change that cannot be predicted to occur in a manufacturing system in the future. Figure 5 shows that the traditional manufacturing system in terms of flexibility and efficiency is very difficult to fulfill both of these, while additive manufacturing can optimize the level of efficiency when maximizing terms of flexibility.

Nowadays the methods of designing and architectural models use digital computer systems, so the products produced are digital products that require the use of software and tools. Current architecture is a global type with design results and models that result from technological development and evolution of computer development (Schumacher, 2008). The character of the architectural product is a result of changes in moderation (Oxman, 2017). The method is called parametric design, in British Journal, Architectural Design (AD) Patrick Schumacher Parametric Design, as a paradigm and penetration of a discipline using systematic adaptive, variation and continuous differentiation (more than a variability in bloom), and also dynamic parametric models used by all fields engaged in product design from urbanism reaches the level of detail tectonic (micro-design and macro models as well as details of the particular complexity) of interior furnishing and world products (Schumacher, 2008).

Material design fabrication is an architectural product that is currently developing as a new material in architectural practice (Oxman, 2012). This new innovation in the field of architecture. Materials are used as elements in building design to improve building performance and aesthetics. The innovations of these materials are produced by modern

fabrication techniques (3D printing, laser cutter, CNC). Digital materiality is a digital materialization process that contributes to the innovation of the current type of material called digital tectonic (Gramazio, Kholer, & Oesterle, 2010; Oxman, 2010). The technology of producing architectural materials produced is a prototype that is produced quickly with the use of technology. This answers the market for architectural products with a design innovation and computer models produced through the digital fabrication system.

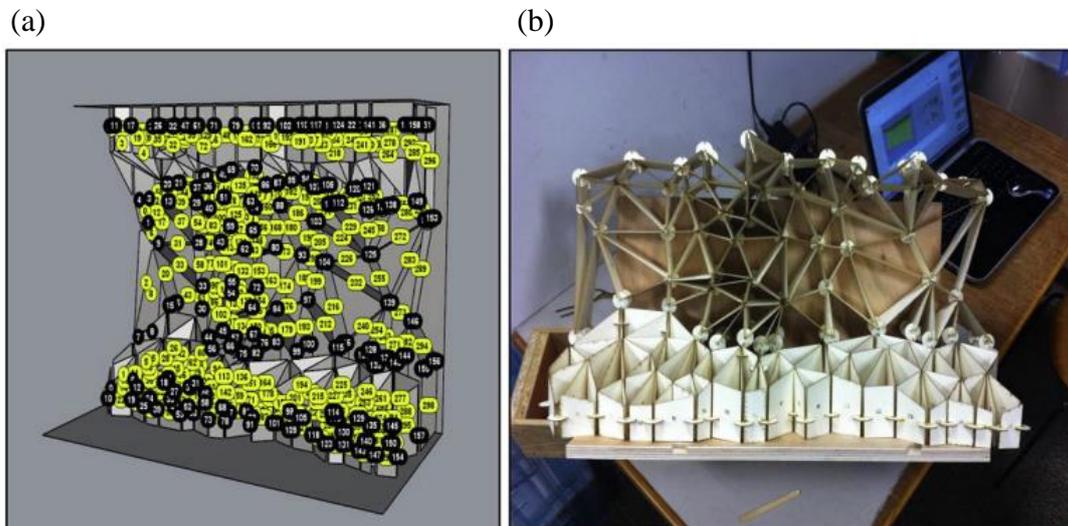


Figure 11. Mechanical digital parametric (a) and assembling product (b)  
(Source: Oxman, 2017)

In Figure 11 is the production of the design and architectural model and its production using the parametric method. Visualize computer design with software Rhinoceros and Grasshopper (left). Parametric model prototype that has been produced using 3D Printing and laser cutting. These designs, models, and products can only be designed through computerization with certain complexity as a customization product.

### 5.3 Social and Cultural Changes

In the last two decades, digital technology has influenced changes in community culture (Kulesz, 2016), creation forms of industrial world revolution in the digital era, impact on computational and communication production that produces a design or model physically and rather than just a virtual computer. Digital fabrication facilitates for each individual to design and produce an object according to the amount of market demand (Gershenfeld, 2012). The influence of industry in the digital era has resulted in changes in social structure and culture of society due to the absence of boundaries from each country, city, and region that is interconnected with another through digital connections, decreased social interaction, then the world community culture that exchanges results in cross cultural.

Referring to the issue of architectural production design, digital fabrication is the new method in the era of digital development. Architectural production requires ideas from the design that will be produced and increases in the quality of the creative industry market in architecture. The digital age embodies of the local creative industry have grown rapidly and get the same market opportunities as creative industries. Digital fabrication architecture

results in a new form of social and cultural change. Post-industrial production utilizes technologies, such as CAD, 3D printing, laser cutting has a very big role in production design, this is a new way of designing a new product to facilitate human needs, resulting in the production of fast design products with more generative forms (Çakmakçioğlu, 2017).

Research conducted by Çakmakçioğlu (2017) on the effects of the digital era influences cultural values. Digital design produces a new form of culture in all aspects of life. Revolution in design does not only refer to mere forms, but is also an alternative that contains meaning, history comprehensively. This shows the meaning of design products influencing values and aspects of life. Cultural values are an inclusive concept in life; culture in the viewpoint of anthropology can be defined as a form of human life and lifestyle (Çakmakçioğlu, 2017), while design is a root of processing an idea (Sparke, 2013). According to Leong & Clark (2003), the essence of culture has three layers: the outer tangible layer, which is a form of a culture; the second is the mid-tangible layer which is behavior, ritual, and tradition; and the third is the inner tangible layer, which refers to trust and the religious community.

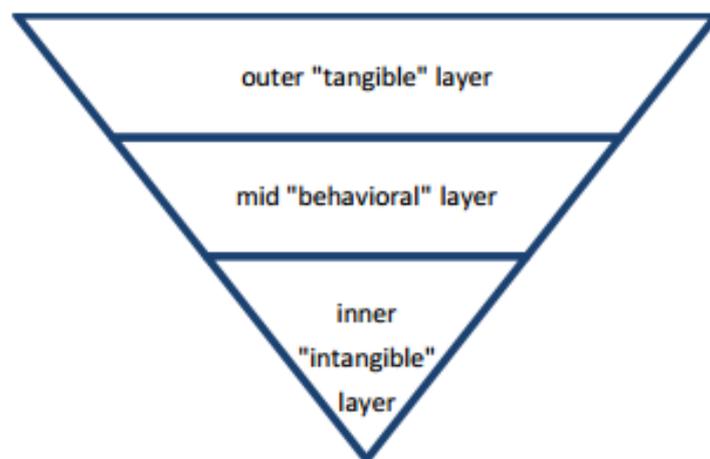


Figure 12. Three layers of space perspective of a culture  
(Source: Leong & Clark, 2003)

The level of culture in the perspective of outer, mid, and inner layers (Figure 12) and their relationship with the design have the same essence, where the design has a form or material in the form of shapes, colors, texture patterns, and others (outer), then design has functions, usability, (mid) and design has meaning, philosophy, and others.

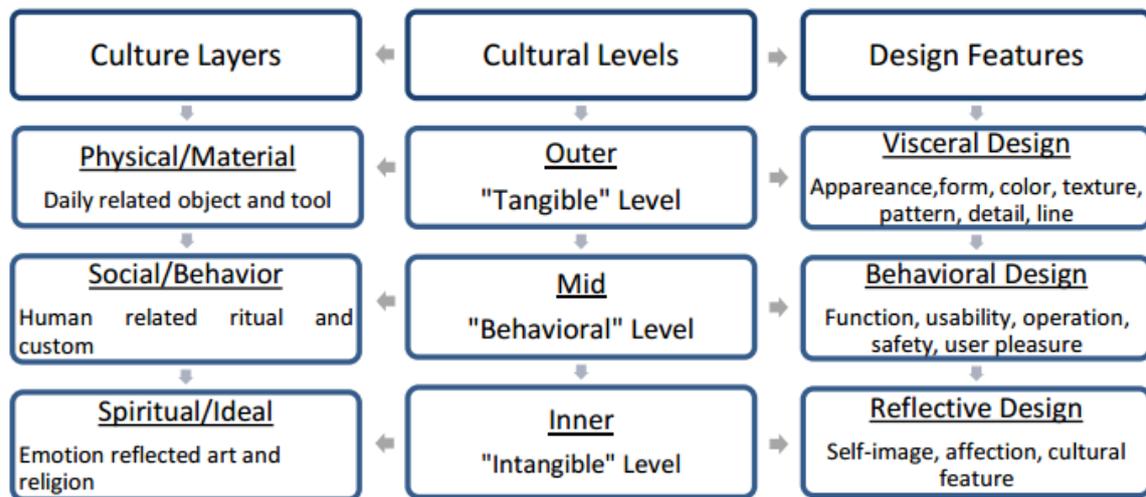


Figure 13. Three layers and levels of cultural objects and designs  
(Source: [Lin, 2005](#); [Lin, 2006](#))

The relationship between design and culture at each level (Figure 13), this shows that design and culture have the same level of form. Changes in the way transfer of cultural values through products, while the value of a design product represents cultural values ([Çakmakçioğlu, 2017](#)). Design as a practice and produce a practice as a closed system, not only as a whole but also the relationship of other cultural systems as literature, such as film, philosophical painting, geometry, and others. Design architecture is the result of an idea of a problem context, from the results of a design product. This reflects the value of an architectural product that reflects the cultural values of an area and is also influenced by the knowledge of the designer.



Figure 14. Functional ceramic product made in 3D printing.  
(Source: [Heuvel, 2014](#))

The production of ceramic vases (Figure 14) using 3D printing reflects a new cultural value, whereas handmade methods (Figure 15) result in a conventional product, which contain local cultural values and local wisdom derived from ancient generation. The

production of other architectural designs using digital fabrication provides a lot of benefits in addition to rapid production levels and in large quantities in a shorter period of time. The production of architectural design in the digital era does not only transform culture through its production (digital fabrication), but also in terms of its material use. Digital fabrication production techniques greatly affect the culture of each region, the production of architectural design is influenced by the locality of each region, so that the design of architectural products transfer each other through the design of products across borders (borderless), and influence each other from design throughout the world.



Figure 15. Hand-made flower vase products  
(Source: [Çakmakçioğlu, 2017](#))

The value of cultural transfer through architectural product design is very influential, the degradation of cultural values in an area, and also results in the existence of new cultural forms called world culture ([Frampton, 1981](#)). Changes local cultural values on the digital era are influenced by several factors, such as digital trade, where everyone can access information and buying and selling transactions through internet access, causing intercultural transfers through architectural products that are so fast, some products dominate the market and some locality products degraded caused by some local products considered ancient by modern society, and digital era of architectural products designed to use computers (Figure 16) with complex variations in developing natural forms, or abstract shapes and geometries using computer algorithms. World cultural is a new culture in the digital era, the phenomenon of intercultural transfer through architectural products with computer design creates a new culture (digital culture) where all architectural products are the same throughout the world due to computer design, the emergence of new cultural values, digital culture dominates, the values of local wisdom of each country will be lost so that later there will be cultural homogeneity throughout the world. The order and shape of each region are the same, buildings that are towering with shapes and materials designed with computers (parametric design), so that each region will disappear. [Ricoeur \(1961\)](#) in his criticism of universal civilization and national culture said that the phenomenon of cultural universalization is an increase in civilization for humanity, on the other hand, is a destruction of a traditional culture that may not be irreparable. It was also realized in [Frampton \(1981\)](#), with his idea to try to protect regional culture due to the influence of world culture universalization (world culture). In

*Critical Regionalism* accommodates the value of local culture with the influence of globalization by adjusting the historical context, culture, climate of the place and also local wisdom.



Figure 16. Computer-made flower vase products  
(Source: [Çakmakçioğlu, 2017](#))

Building design is relative of local culture according to contextual issues. Shape of building also integrate local context, its type of building ([Frampton, 1981](#)). Building types are performing and representing local value of each region. Digital era can eliminate types of building with new digital design of building with general types of building in the rest of the world.

Cultural value transfer through architectural products in the digital era also results in social impacts of society. Increased production of architectural products with digital systems (digital fabrication) increases the number of machines so as to reduce the number of workers (employees). The loss of the nature of humanity in production can lead to social conflicts and a decline in the quality of human resources, increased poverty rate, increased health hazards, and decreased skills (education). The fourth industrial revolution is the era of smart computer technology, which enhances or can help explore architectural design with computer systems; on the other hand, it can reduce human creativity for design. In addition, this has changed civilization, and human living standards are increasing, with 1% of the richest people controlling more than half of the world market that is engaged in the digital industry article, reducing the number of human workers as a result of machinery. Research on the social impact of digitalization includes the loss of some jobs and, consequently, the pressure of labor demand ([Katz, 2017](#)). In addition, research shows the digital age eliminates work at the middle level ([Goos & Manning, 2007](#); [Goos, Manning, & Salomons, 2009](#)). As a result of the reduction of lower-middle class jobs, new jobs emerge, including online auction and video and audio streaming, and web design.

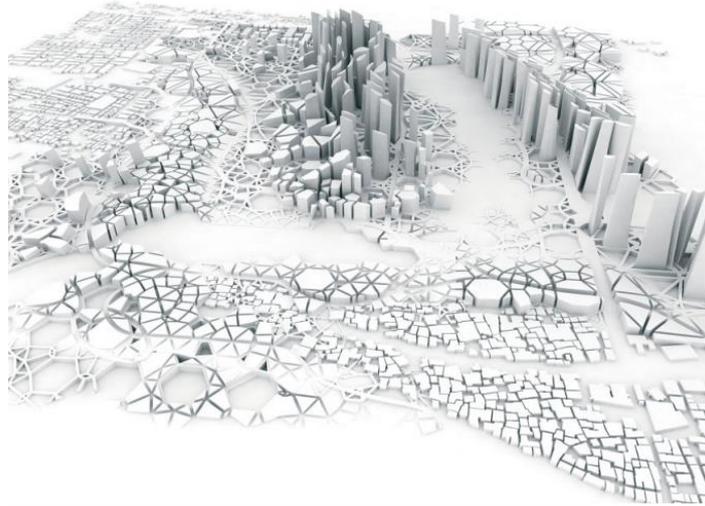


Figure 17. Product digital design  
(Source: ZHA Architect, 2019)

Digital architectural design and production can also eliminate the work related to product design, such as the architectural profession, as design is created with computer algorithms, such illustrated in Figure 17. Demanding quality human resources in the digital age need to be improved especially in terms of creativity so that they can complete with new market methods in the digital era. Professionals in architecture and other design fields are required to be more innovative in the digital era to remain relevant; innovations about design ideas and contextual problems are required to solve environmental problems, which computer technology is incapable of fulfilling. Computers are only tools to help humans solve problems and create a product. Seeing the social and cultural side in the digital era represents a highly developed civilization; however, this resulted in the changes in the culture or loss of local wisdom as well as loss of jobs.

## 6. Conclusion

The development of technology in architecture and construction has a significant impact on the design, production, and manufacturing processes. This is driven by the rising need of people and the increasing demand, resulting innovations that could slash out a lot of processes. The current digital era in the field of architecture and construction to enhance design and innovation product rapidly and mass production techniques. The development of technology in production in the digital era resulted in a significant innovation (digital fabrication). This raises the question of whether innovation has a significant impact on the environment (environmental damage, economic improvement, degradation of social and cultural values, etc.), but in other cases it enhances innovation and paves the way for innovative architectural design.

The impact of digital fabrication on the environment includes climate change, ozone depletion, human toxicity, water depletion, metal depletion, and fossil depletion. It can be concluded that architectural products in the digital era has a huge impact on the environment as compared to conventional design. Production of architectural design in the digital era can improve the economy, significantly increasing where all industries obtain information from

cross-border market demand between countries. Digital fabrication methods can answer the challenges of the market in the digital era; on the other hand, digital architectural innovation can affect cultures throughout the world, including degradation of cultural values and depletion of local products considered ancient, and then creating a universal digital culture (universal culture). Architectural production in the digital era also affects social systems, advances civilization, and reduces the number of middle-class workers because of the emergence of new jobs through online, digital design, online shops, among others.

Architectural production in the digital era is a development of civilization; on the other hands it large affects the environment in terms of environmental damage, economic improvement, and degradation of social and cultural values. Therefore, the need for human awareness of both producers and consumers to maintain the environment by controlling demand and production. Maintaining local cultural values and wisdom without being influenced by other cultures by understanding the context of local problems, considering the history, climate, weather and local cultural values in creating architectural product designs, while enhancing the quality of human resources to enhance ideas, innovations, and the creativity of each individual so they can compete in the market in the digital era.

## References

- Agrest, D. (1974). Design versus Non-Design, *Oppositions*, 6.
- Altan, T., Lilly, B. B., & Yen, Y. C. (2001). Manufacturing of dies and molds. *CIRP Annals*, 50(2), 404–422. [https://doi.org/10.1016/S0007-8506\(07\)62988-6](https://doi.org/10.1016/S0007-8506(07)62988-6)
- ASTM International. (2012). Standard Terminology for Additive Manufacturing Technologies. Designation: F2792e12a. Retrieved from [http://www.astm.org/FULL\\_TEXT/F2792/HTML/F2792.htm#Nav0007](http://www.astm.org/FULL_TEXT/F2792/HTML/F2792.htm#Nav0007)
- Baubiologie. (1975). *Institute for Baubiologie by Anton Schneider*.
- Çakmakçioğlu, B. A. (2017). Effect of Digital Age on the Transmission of Cultural Values in Product Design. *The Design Journal*, 20(1), S3824–S3836. <https://doi.org/10.1080/14606925.2017.1352886>
- Cavallin, H. (2009). *Caliphs, Intentionalities, and the Design Process: Architecture-Design Methods-Inca Structures*. Kassel: Kassel University GmbH.
- Chen, D., Heyer, S., Ibbotson, S., Salonitis, K., Steingrímsson, J. G., & Thiede, S. (2015). Direct digital manufacturing: definition, evolution, and sustainability implications. *Journal Cleaner Production*, 107, 615–625. <https://doi.org/10.1016/j.jclepro.2015.05.009>
- Copenhagen. (2009). *Climate Change Conferences: The 15th Session of the Conference of the Parties*.
- Drizo, A., & Pegna, J. (2006). Environmental impacts of rapid prototyping: an overview of research to date. *Rapid Prototyping Journal*, 12, 64–71. <https://doi.org/10.1108/13552540610652393>
- Eyers, D. R., & Potter, A. T. (2015). E-commerce channels for additive manufacturing: an exploratory study. *Journal of Manufacturing Technology Management*, 26, 390–411. <https://doi.org/10.1108/JMTM-08-2013-0102>
- Frampton, K. (1981). Critical Regionalism. *Issues in the Practice of Architecture*.
- GBC. (2016). Retrieved from <https://www.worldgbc.org/benefits-green-buildings>.

- Gershenfeld, N. (2012). [How to make almost anything: the digital fabrication revolution](#). *Foreign Affairs*, 91(6), 43–57. Retrieved from <http://cba.mit.edu/docs/papers/12.09.FA.pdf>
- Gibson, I., Rosen, D. W., & Stucker, B. (2010). Direct digital manufacturing. In I. Gibson, D. Rosen, & B. Stucker (Eds.), *Additive Manufacturing Technologies* (pp. 378–399). New York: Springer. [https://doi.org/10.1007/978-1-4939-2113-3\\_14](https://doi.org/10.1007/978-1-4939-2113-3_14)
- Goos, M., & Manning, A. (2007). [Lousy and lovely jobs: The rising polarization of work in Britain](#). *The Review of Economics and Statistics*, 89(1), 118–133. Retrieved from <https://www.jstor.org/stable/40043079>
- Goos, M., Manning, A., & Salomons, A. (2009). [Job Polarization in Europe](#). *The American Economic Review*, 99(2), 58–63. Retrieved from <https://www.jstor.org/stable/25592375>
- Gramazio, F., Kohler, N., & Oesterle, S. (2010). Encoding material. In R. E. Oxman, & R. M. Oxman (Eds.), *The New Structuralism: Design, Engineering and Architectural Technologies, Architectural Design (AD)* (pp. 108–115). Wiley and Sons. <https://doi.org/10.1002/ad.1101>
- Hague, R., Campbell, I., & Dickens, P. (2003). [Implications on design of rapid manufacturing](#). *Proceedings of the Institution of Mechanical Engineers, Part C: Journal of Mechanical Engineering Science*, 217(1), 25–30. <https://doi.org/10.1243/095440603762554587>
- Heuvel, V. D. D. (2014). [Functional 3D Printed Ceramics](#). Retrieved from <http://oliviervanherpt.com/functional-3d-printed-ceramics/>
- Holmström, J., Liotta, G., & Chaudhuri, A. (2017). [Sustainability outcomes through direct digital manufacturing-based operational practices: A design theory approach](#). *Journal of Cleaner Production*, 167, 951–961. <https://doi.org/10.1016/j.jclepro.2017.03.092>
- Hopkinson, N., & Dickens, P. (2001). [Rapid prototyping for direct manufacture](#). *Rapid Prototyping Journal*, 7, 197–202. <https://doi.org/10.1108/EUM0000000005753>
- Hudson, R. (2010). *Strategies for parametric design in architecture: An application of practice led research*. Bath: University of Bath.
- Iwamoto, I. (2004). [Embodied Fabrication: computer-aided spacemaking](#). *AIA/ACADIA Fabrication Conference*, 270–278. Retrieved from [http://papers.cumincad.org/data/works/att/acadia04\\_270.content.pdf](http://papers.cumincad.org/data/works/att/acadia04_270.content.pdf)
- Juan, I. A., & Habert, G. (2016). *Environmental Design Guidelines for digital fabrication*, Zurich: Elsevier Ltd.
- Jones, J. C. (1970). *Design Methods: Seeds of Human Future*. New York and Chicester: John Wiley and Sons.
- Katz, R. (2017). [Social and Impact of Digital Transformation on the Economy](#). ITU. Retrieved from [https://www.itu.int/en/ITU-D/Conferences/GSR/Documents/GSR2017/Soc\\_Eco\\_impact\\_Digital\\_transformation\\_finalGSR.pdf](https://www.itu.int/en/ITU-D/Conferences/GSR/Documents/GSR2017/Soc_Eco_impact_Digital_transformation_finalGSR.pdf)
- Khajavi, S. H., Partanen, J., & Holmstrom, J. (2014). [Additive manufacturing in the spare parts supply chain](#). *Computers in Industry*, 65, 50–63. <https://doi.org/10.1016/j.compind.2013.07.008>

- Kolarevic, B. (2001). [Digital Fabrication: Manufacturing Architecture in The Information Age](#). *ACADIA Modeling and Fabrication*, 4, 268–278. Retrieved from <https://cumincad.architexturez.net/doc/oai-cumincadworks-id-81b8>
- Kulesz, O. (2016). [The Impact of Digital on the Diversity of Cultural Expression in Spain and Hispanic America](#). UNESCO. Retrieved from [https://fr.unesco.org/creativity/sites/creativity/files/sessions/10igc\\_inf4\\_the\\_impact\\_of\\_digital\\_technologies\\_octavio\\_kulesz\\_en\\_0.pdf](https://fr.unesco.org/creativity/sites/creativity/files/sessions/10igc_inf4_the_impact_of_digital_technologies_octavio_kulesz_en_0.pdf)
- Kyoto Protocol. (1997). *The United Nations Framework Convention on Climate Change adopted at COP3 in Kyoto, Japan*.
- Leong, D., & Clark, H. (2003). [Culture-based knowledge towards new design thinking and practice—A dialogue](#). *Design Issues*, 19(3), 48–58. Retrieved from <https://www.jstor.org/stable/1511964>
- Lin, R. T. (2005). Creative learning model for cross cultural product (in Chinese). *Art Appreciation*, 1(12), 52–59
- Lin, R. T. (2006). Scenario and story-telling approach in cross cultural design (in Chinese). *Art Appreciation*, 2(5), 4–10.
- Manyika, J., Lund, S., Bughin, J., Woetzel, J., Stamenov, K., & Dhingra, D. (2016). [Digital Globalization: The New Era of Global Flows](#). McKinsey Global Institute. Retrieved from <https://www.mckinsey.com/business-functions/digital-mckinsey/our-insights/digital-globalization-the-new-era-of-global-flows>
- Mardones, J., Iori, G., Becerra, A., Diaz, M., & Zagal, J. C. (2012). [Using Digital Fabrication on Small Satellite Projects](#). *Proceedings of the International Symposium on Small Satellites Systems and Services-4S Symposium*. Retrieved from <http://jczagal.com/publications/mardones2012.pdf>
- McKinsey Global Institute. (2016). *Digital Globalization: The New Era of Global Flows*. McKinsey and Company.
- McMahon, C. and Browne, J. (1998), *CADCAM: Principles, Practice, and Manufacturing Management*. Massachusetts: Addison-Wesley.
- Onuh, S. O., & Yusuf, Y. Y. (1999). [Rapid prototyping technology: applications and benefits for rapid product development](#). *Journal of Intelligent Manufacturing*, 10, 301–311. <https://doi.org/10.1023/A:1008956126775>
- Ortiz, O., Castells, F., & Sonnemann, G. (2009). [Sustainability in the construction industry: A review of recent developments based on LCA](#). *Construction and Building Materials*, 23(1), 28–39. <https://doi.org/10.1016/j.conbuildmat.2007.11.012>
- Oxman, N. (2010). Structuring materiality: Design fabrication of heterogeneous materials. In R. E. Oxman, & R. M. Oxman (Eds.), [New Structuralism: Design, Engineering and Architectural Technologies](#) (pp. 78–85). Wiley and Sons. <https://doi.org/10.1002/ad.1101>
- Oxman, R. (2006). [Theory and design in the first digital age](#). *Design Studies*, 27(3), 229–265. <https://doi.org/10.1016/j.destud.2005.11.002>
- Oxman, R. (2012). [Informed tectonics in material-based design](#). *Design Studies*, 33(5), 427–455. <https://doi.org/10.1016/j.destud.2012.05.005>
- Oxman, R. (2017). [Thinking different: Theories and models parametric design thinking](#). *Design Studies*, 52, 4–39. <http://dx.doi.org/10.1016/j.destud.2017.06.001>

- Ricoeur, P. (1961). *Universal Civilization and National Cultures*. Evanston: Northwestern University Press.
- Rio Declaration. (1992). *United Nations Conference on Environment and Development. Agenda 21, Forest Principles*. New York: United Nations.
- Ryder, G., Ion, B., Green, G., Harrison, D., & Wood, B. (2002). [Rapid Design and Manufacture Tools in Architecture](#). *Automation in Construction*, 11(3), 279–290. [https://doi.org/10.1016/S0926-5805\(00\)00111-4](https://doi.org/10.1016/S0926-5805(00)00111-4)
- Saghafi, M. R., Mozaffar, F., & Moosavi, S. (2015). [Teaching Methods in Architectural Dessig Basic](#). *Ciência e Natura, Santa Maria*, 37(1), 379–387. Retrieved from <https://pdfs.semanticscholar.org/5394/7cf6c762e4f555020e1eb865e036f84fb4d4.pdf>
- Salim, F. N. (2010). *The Impact of Globalization on Architecture and Architectural Ethic*. Auckland: University of Auckland.
- Sass, L. (2006). [Synthesis of design production with integrated digital fabrication](#). *Automation in Constructions*, 16, 298–310. <https://doi.org/10.1016/j.autcon.2006.06.002>
- Schumacher, P. (2008). *Parametrism as a Style - Parametrism Manifesto*. London: New Architectural Group.
- Sparke, P. (2013). *An Introduction to Design and Culture*. New York: Routledge.
- Thiesse, F., Wirth, M., Kemper, H.-G., Moisa, M., Morar, D., Lasi, H., Piller, F., Buxmann, P., Mortara, L., Ford, S., & Minshall, T. (2015). [Economic Implication of Additive Manufacturing and the Contribution of MIS](#). *Business & Information Systems Engineering*, 57(2), 139–148. <https://doi.org/10.1007/s12599-015-0374-4>
- UIA. (1993). *World Congress of Architect*. Japan.
- UNEP. (2012). [Building Design and Construction: Forging Resource Efficiency and Sustainable Development](#). UNEP. Retrieved from <https://www.usgbc.org/drupal/legacy/usgbc/docs/Archive/General/Docs19073.pdf>
- Vazquez, A. N., & Jabi, W. (2015). [A collaborative to digital fabrication: A case study for the design and production of concrete ‘Pop-up’ structures](#). *International Journal of Architectural Computing*, 13(2), 195. <https://doi.org/10.1260/1478-0771.13.2.195>
- Wardah, E. S. A. A., & Khalil, M. O. (2016). [Design Process and Strategic Thinking in Architecture](#). *Proceedings of 2nd International Conference on Architecture, Structure and Civil Engineering*. Retrieved from [https://www.researchgate.net/publication/328130631\\_Design\\_Process\\_Strategic\\_Thinking\\_in\\_Architecture](https://www.researchgate.net/publication/328130631_Design_Process_Strategic_Thinking_in_Architecture)
- Whitehead, H. (2003). Laws of form. In B. Kolarevic (Ed.), *Architecture in the Digital Age: Design and Manufacturing* (pp. 89–113). Taylor and Francis.
- Wohlers, T., & Caffrey, T. (2013). *Wohlers report 2013: Additive manufacturing and 3D printing state of the industry*. Fort Collins: Wohlers.
- Woodbury, R. F. (2010). *Elements of parametric design*. New York: Routledge.
- Wortmann, T., & Tunçer B. (2017). [Differentiating Parametric Design: Digital Workflows in Contemporary Architecture and Construction](#). *Design Studies*, 52, 173–197. <https://doi.org/10.1016/j.destud.2017.05.004>
- Wright, F. L. (1930). *The Architectural Forum*. New York: National Trade Journals, Inc.
- Zeid, I. (1991). *CAD/CAM Theory and Practice*. New York: McGraw-Hill.
- ZHA Architect. (2019). [Zaha Hadid Architects](#). Retrieved from <https://www.zaha-hadid.com/>