Changing the architectural production chain in Latin America with the introduction of new technologies

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ABSTRACT
In the past decades, new technologies coming from the high-tech industry have been introduced in architectural design and the building process. In this article we show how the gap between design and production was filled in the developed world and discuss how the file-to-factory method could be implemented in the Latin American context.

The design and construction of buildings have undergone major transformations since the late twentieth century, with the introduction of new methods and technologies, such as building information modeling (BIM), parametric design, rapid prototyping and digital fabrication. In Latin America, as recently shown by the "Homo Faber" exhibition, digital fabrication laboratories are becoming more common, levering innovation in architectural design both in academia and practice. At the same time, it is possible to affirm that state-of-the-art computer-numerical control (CNC) equipment is present in many industrial sectors in our region. However, architects are usually not aware of that, and oftentimes what is designed with state of the art software is produced with traditional building techniques.

In this article we will first look at the concepts of flexible production, mass-customization and parametric design, and the recent introduction of these new methods in the architectural design and building process in the developed world and in Latin America. We will also show evidences of the existence of an installed base of computer-controlled industrial equipment in the region, with the availability of state-of-the-art machines in many industrial sectors, due to a significant recent price decrease. We will then see how the gap between architectural firms and these new production methods has been bridged in developed countries. Finally, we will discuss the difficulties and advantages of the file-to-factory method, and how it could be implemented by architectural firms in Latin America.

Since the first industrial revolution, marked by the invention of the mechanical loom, in 1784, the introduction of new technologies has significantly transformed production methods. Each of those had important impacts in architecture and urban design. In the early 20th century, the Second Industrial Revolution was characterized by the concept of mass-production and economy of scale. In the 1970s, the introduction of computer-controlled machines changed these logics of industrial production, resulting in a Third Industrial Revolution. The main characteristic of these machines is flexibility, which means that they have the ability to create different product types, or run the same procedures with different parameters, allowing the mass production of individually-designed parts. A good example of flexible manufacturing machine is the laser cutter. Instead of investing in a specific knife for cutting a specific shape, factories are now investing in machines that can cut any shape specified by a digital file. This concept is called file-to-factory, and it also applies to 3D-printing and CNC direct carving, which can substitute expensive molds. There are also new developments in flexible, CNC-controlled pin-molds, for example for the production of double-curved glass or metal panels.

The concept of mass customization, first identified by Stan Davis in Future Perfect *(1987), has been explored by architects as a new production method that can completely eradicate repetition and boredom from buildings. Frank Gehry's Guggenheim Museum in Bilbao, built in 1997, is acknowledged as the first large-scale building to effectively employ this technology. In this building, thousands of sections of its titanium façade were individually curved with a computer-controlled calender, which made the work feasible, at least timewise . The Neuer Zollhof housing complex in Düsseldorf, finished in 1998 and also designed by Gehry, is another early example of the use of CNC technology in the building process, in this case for carving huge foam blocks that were used* *as molds for casting curved concrete panels.*

In order to be able to take advantage of the new flexible production methods, Frank Gehry's office had to adopt, at least initially, CAD/CAM parametric software that was originally developed for the air-space industry, which was much more powerful than the CAD software then used by architects. This required close interaction with software engineers, and eventually led to the development of Digital Project, a software based on Dassault Systèmes[1] CATIA, with a new visual interface, more suitable for architectural design. Other technologies adopted by Gehry's office that also came from the mechanical industry were 3D-scanning and rapid prototyping[2].

In 2001, the SmartGeometry group was founded in Europe, "as an informal network of designers interested in harnessing the powers of computation for architectural design" (Peters & Peters, 2013, p. 8). Their work led to the development of another revolutionary program that was also oriented to parametric design and CNC production: GenerativeComponents. Used in practice since 2005 and commercially released in 2007, GC was based on Bentley's CAD system, and was developed in close collaboration with another leading architectural office, Foster + Partners.

This paradigm shift in architecture – the use of parametric software for designing and modeling, and the production of free-form building parts with CNC-controlled machines – was acknowledged by critics, such as Branko Kolarevic in Architecture in the Digital Age: Design and Manufacturing *(2003), and featured in exhibitions, such as "Architectures non standard", at the Centre Georges Pompidou in Paris (2002-2003), and "Home Delivery: Fabricating the Modern Dwelling", at the Museum of Modern Art (MoMA) in New York (2008).*

Since then, these methods have been adopted by many architectural practices and schools, thanks to a dramatic decrease in the cost and an increase in the availability of software and machines, in special 3D-printers and laser cutters. Grasshopper[3], a visual programming language developed by David Rutten on McNeel's CAD software platform (2008), is presently the most popular parametric modeling software due not only to its low cost, but also to the fact that it does not necessarily require programming skills. At the same time, low-cost rapid prototyping machines have also become available. 3D printers, for example, which used to cost US$20,000 until 2010, are now sold for less than US$500.

The first Latin American groups interested in the application of parametric design and digital fabrication in architecture were founded in the early 2000s, usually within universities, by scholars who had developed their graduate studies in Europe and the US. By then, parametric design was usually implemented by writing text-base algorithms, using programming languages such as Autolisp, VBA for AutoCAD or Rhinoscript. The popularization and increasing affordability of parametric modeling software and rapid prototyping machines resulted in the founding of many new research groups and laboratories devoted to this themes since 2010.

In 2015, the "Homo Faber - Digital Fabrication in Latin-America[4]" exhibition, held in São Paulo, showed that these new technologies were already well-established in the region. "Homo Faber" was curated by professors David Sperling and Pablo Herrera, respectively from the University of São Paulo and from the Peruvian University of Applied Sciences, featuring 25 of the 70 estimated laboratories and research groups acting in the field. Two thirds of the participating labs had been created in the previous three years, which shows how the movement really spread out after 2010. The great majority of them was linked to universities, probably due to the cost of investments, but there were also some new labs being created at private practices, which will probably be a tendency with the drop in costs of digital fabrication machines. The curators also pointed to "the predominance of applications in the production of small objects" (Sperling & Herrera, 2015, p. 10) – i.e. scale models and small prototypes – instead of applications in the direct production of building parts, such as in concrete molds.

One of the architectural offices featured in "Homo Faber" was Frontis 3D[5], from Bogotá, leaded by architect Rodrigo Velasco, which presented Neutral Voronoi, a façade system made of laser-cut metal components. In the early 2000s, after graduating in Architecture in the National University of Colombia, Velasco developed graduate studies in Computational Design in Germany, at the Hochschule Ostwestfalen-Lippe, and then worked in research projects and practice at the University of Nottingham, England, and in Hong-Kong.

Another practitioner featured in the exhibition was SUBdV[6], an office originally founded in London by Brazilian architect Franklin Lee and American architect Anne Save de Beaurecueil. They have taught at the

Pratt Institute and Columbia University in New York in the early 2000s, where they also received their Master's degrees. Beaurecueil has also worked in leading practices such as the offices of Zaha Hadid in the UK and Ken Yeang in Malasia. From 2005 to 2010, Lee and Beaurecueil were instructors at the Architectural Association in London, and then moved to São Paulo, where they conduct the 2010 AA São Paulo Visiting School. Since them, their focus has been on how to apply the new technologies that they used in the developed world to the Brazilian context, with an approach they call "high-low fusion". SUBdV presented a project named CoBLOgó, a reference to the traditional Brazilian shading screen – the cobogó. *The project consists of a parametrically designed façade inspired by Gramazio and Kohler's work at ETH Zürich. In this tropical version, however, cheap concrete blocks are used instead of high quality ceramic bricks, and the brick-laying industrial robots are substituted by digitally-cut guides that were used to conduct the block-laying by unskilled workers.*

Protobox[7] is another example of this new generation of practitioners, but in this case both partners – Wilson Barbosa Neto and Renata la Rocca – have developed their graduate studies in Brazil, as advisees of professors who did their PhDs abroad, respectively at MIT and Sorbonne. It is important to note, however, that Barbosa also had a practicing experience in Sidney, Australia, where he first had contact with the use of digital fabrication for the construction industry. This recently-founded (2015) Campinas-based office presented Dobrá, a parametrically-designed outdoor furniture collection that was custom-produced with CNC plasma-cutting and metal-bending machines. What is interesting about this project is the fact that the furniture does not have any particularly challenging wavy form. On the contrary, the design is pretty simple and almost modern, but the office was able to prove how the use of digital fabrication can be advantageous even for non-extreme designs. It is also important to stress that Barbosa's knowledge on this type of production process was the result of his internship at a local high-tech metallurgic industry during his Master degree studies at the University of Campinas[8].

All the examples described above consist of small architecture offices acting in an almost subversive way, looking for alternative projects and open-minded commissioners, and desperately avoiding to fall in the boredom of the established system, which tends to respond directly to the real-estate market. One of the reasons why they have been successful in introducing new design methods into practice is the availability of CNC equipment in their regions. In 2009, during a SIGraDi conference in São Paulo, Latin America's annual summit on digital architecture and design, Professor Neander Furtado Silva, from the National University of Brasilia, demonstrated that the Brazilian industry was already equipped with state-of-the-art computer-controlled machines, which could made architect's file-to-factory process a reality (Furtado Silva, Bridges, Lima, Aguiar Morais, & Silva Júnior, 2009). He pointed to the possible implications of this installed base to the future of Brazilian architecture, considering the possibility of incorporating mass-customization in the architecture and construction process, allowing to produce complex shapes at reasonable costs.

A quick internet survey shows that not only Brazil, but also Chile, Colombia, Peru, Mexico and Argentina, and probably other Latin American countries as well, are equipped with CNC-machines in many industrial sectors. I have witnessed some of those extremely sophisticated machines being used to cut simple squares and circles, while they could be cutting extremely complex, interlocking shapes out of a parametric model at no extra cost. The economic crisis that the region is presently going through, could be an opportunity for architects to start using the machines standing idle in this particular moment, as suggested by Kolarevic (Celani, 2013), but... are architects ready for that? Although these new paradigms are starting to be introduced in many architecture schools, it takes time to change the culture, and the knowledge gained in academia is not always enough for starting a new type of practice.

As I pointed in a recently published paper (Celani & Lenz, 2014), in order to bridge the gap between the creative process and CNC production, three different solutions have been used in Europe and the US: in-house teams, specialized consulting firms, and services offered by the industry. In the early 2000s, in order to address the need for resolving the design and construction of ever more complex buildings, such as the Swiss RE in London, large offices were in need of professionals with interdisciplinary skills, who could handle advanced geometry and digital fabrication issues. This is how Foster + Partners created the Specialist Modeling Group[9] and how Arup created its Advanced Geometry Unit[10]. However, this is an expensive solution that only the largest architecture and engineering firms can afford. As medium sized firms started to need the same type of *services, independent consultancies have been established, such as Designtoproduction[11], a Stuttgart and Zürich based firm that has helped offices such as UN Studio, Renzo Piano's and Shigeru Ban's. Among the services provided by these consultants are the parametric modeling of complex shapes and the tessellation and rationalization of surfaces, allowing them to be built at a reasonable cost. Finally, for small practices, some industries have created special departments that help architects translate their design ideas into CNC-made components. Such is the case with American firms Metalab[12], Milgo[13], and Zahner[14].*

In Latin America we have not found any formal examples of the three types of solutions described above, although there might be some individual consultants acting in the area in special occasions. These types of support has proved to be fundamental for the integration between architecture and new production methods in developed countries and they could be a potential niche for young Latin American architects willing to gain experience in the field.

If we look at the digital architecture paradigm as an intersection between architectural design and industrial developments, instead of adopting the glamorous technological view of the stararchitects' offices, we can start formulating strategies to bring a new development to Latin American architecture. With that in mind, we do not need to fear the direct translation of out-of-context international styles, which simply ignore our predominantly unskilled labor force. Changes must happen at the construction site, and not only at the architect's desk (or, in this case, computer files), as pointed by authors such as Fabricio (2013). A new culture of close collaboration between architects, industries and contractors is possibly the key for the effective assimilation of new technologies in the whole architectural production chain. This could, effectively, change Latin American architectural practice. m

NOTES

(1) Nowadays, new rationalization methods have been developed to make this technology feasible also economically and resource wise.

(2) At that time 'rapid prototyping' was synonym to additive manufacturing, which was still an expensive method under development, which only the car and airspace industries could afford for making scale models and prototypes. Nowadays 'digital fabrication' is more commonly used to refer to all computer-controlled fabrication methods, both for producing prototypes and final parts. '3D-printer' is now the common word for referring to additive manufacturing machines, especially low-cost fusion deposition modeling (FDM) machines..

(3) An early version of Grasshopper was initially released in 2007 under the name Explicit History.

(4) The exhibition catalog is available in https://issuu.com/davidmsperling/docs/homofaber_catalogue.

(5) See http://frontis3d.co/site/en.

(6) See www.subdv.com.

(7) See www.facebook.com/protobox.br/about/?entry_point=page_nav_about_item&tab=overview

(8) See Barbosa Neto, 2013.

(9) See www.fosterandpartners.com/design-services/research/specialist-modelling-group

(10) See https://aefirms.wordpress.com/2011/01/27/arup-advanced-geometry-unit

(11) See http://www.designtoproduction.com

(12) See www.metalabstudio.com

(13) See www.milgo-bufkin.com

(14) See www.azahner.com

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