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404-415 Rodrigo García Alvarado, Underlea Miotto Bruscato

Three Recent Experiences of Architecture and Digital Fabrication

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Tri recentna iskustva na području arhitekture i digitalne proizvodnje

Stručni članak
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Fig. 1 Beijing National Stadium
Sl. 1. Nacionalni stadion u Pekingu

Rodrigo García Alvarado, Underlea Miotto Bruscato

Depto. de Diseño y Teoría de la Arquitectura,
Universidad del Bio-Bio
CL – 3349001 Concepcion, Avda. Collao 1202

Centro de Ciências Exatas e Tecnológicas
Universidade do Vale do Rio dos Sinos
BR – 93022-000 Sao Leopoldo-RS, Av. Unisinos 950, Cristo Rei

Katedra za projektiranje i teoriju arhitekture
Sveučilište u Bio-Biu
CL – 3349001 Concepcion, Avda. Collao 1202

Centar za egzaktne znanosti i tehnologiju
Sveučilište u Vale do Rio dos Sinosu
BR – 93022-000 Sao Leopoldo-RS, Av. Unisinos 950, Cristo Rei

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Three Recent Experiences of Architecture and Digital Fabrication

Tri recentna iskustva na području arhitekture i digitalne proizvodnje

COMPUTER-AIDED DESIGN
CONSTRUCTION PLANNING
DIGITAL MANUFACTURING TECHNOLOGIES
VIRTUAL MODELING

RAČUNALNO POTPOMOGNUTO PROJEKTIRANJE
PLANIRANJE GRADNJE
TEHNOLOGIJE DIGITALNE PROIZVODNJE
VIRTUALNO OBLIKOVANJE

This paper describes designs and execution process of three recent architectural works, namely, the Beijing Olympic Stadium, a rural refuge in southern Brazil, and an educational workshop. Each of them is very different in size and context, but they all use new digital manufacturing technologies. Hence, this paper reveals similar features of their production processes, suggesting that new technologies change time spans and create relationships between design and construction.

Članak opisuje projekte i proces izrade u slučaju tri recentna arhitektonska primjera, odnosno Olimpijski stadion u Pekingu, ruralni zbjeg u južnom Brazilu i edukativnu radionicu. Svaki je od njih vrlo različit po veličini i kontekstu, no svi oni koriste tehnologiju digitalne produkcije. Stoga ovaj članak pokazuje slične osobine njihove produkcije, nagovješćujući da nove tehnologije utječu na raspon vremena produkcije stvarajući tako odnose između projektiranja i same izvedbe.

Introduction[1]

Uvod

Time is probably the most unassailable dimension, gifted with an abstract and intangible condition that, nevertheless, defines the evolution of actions and things. As such it affects efforts involved, services provided and consequent values. In fact, although production is a material activity, the economic cost of products is largely determined by the time implicated in their making or their later consumption. Time has also a cultural sense in that it links actions that occur chronologically close to one another, even though they're spatially dispersed, in a way that different activities, while in the same period, share backgrounds, conditions and projections. It establishes temporal relations and contexts with common requirements and challenges.

Architecture is eminently a perennial reality, linked to enduring physical properties. Its elaboration or temporal situations are perceived distant from the essence of the architectural work. Time has been regarded in modern architecture only like a conceptual inspiration of dynamic shapes.[2] However, time conditions are intrinsically involved with execution and life of buildings much more strictly than it seems. The manufacturing process involves a labor time of professionals and workers, and it happens in a determined period of time according to the present culture.

The design is often conceived as a still picture, such that can be developed in a variable time. It provides a full description of the work, like an instantaneous moment, which can be executed at the moment or much later (or never), even in different ways or places, without affecting its essential features. A depiction of the building presents its permanent status (with the little movement of doors or windows), and the work is expected to be executed precisely and kept unaltered, almost eternally. Its extension in time is not relevant to the design, which is apparently rooted on a static notion of life. But, at least architectural design is a labour effort, measured in professional time, and construction requires a period of work. Also the elaboration of its products and the building's use or lifecycle has effective duration until it collapses or deteriorates, all of which affects the reality of the design.

On the other hand, digital technologies, which have strongly been introduced in design and construction management, are essentially compressed time. The software is a combination of operations previously prepared by programmers that can be used quickly saving time in certain tasks, including information storage. Furthermore, fabrication is the concentration and planning of certain activities in order to elaborate products in a more efficient way. In other words, it takes less time or consumption of materials (which implies lesser effort in their production). Industrialization's central equation is the total time of the product's life and fabrication that equals the time destined to manufacture one unit of the product, plus the time to plan and set each step of batch production, plus the designing and engineering time.[3] In this way, products of industrial fabrication can have lower costs (since less time was spent), they can be produced in bigger amounts and accessible to more people who, by obtaining more products supposedly have a better quality of life.[4] That is a keystone of industrial economies and developed societies in which building sector usually has lower productivity rates (bigger amount of effort in manufacturing products), and a slow evolution in its production process.

Digital manufacturing consists of the control of industrial machinery by electronic information. It is, therefore, a combination of temporal capacities, which allows bigger number and more diverse activities to be done at the same time. According to some studies,[5] companies that use digital manufacturing reduce

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1 Acknowledgement: This paper was done through an international collaboration supported by the research project FONDECYT 1080328

2 Gideon, 1941

3 Scheer, 1995

4 Kieran, Timberlake, 2004

5 De Carli, 2007

fabrication time by 30%, the number of modifications of the design by 65% and the time required by the planning of the manufacturing processes by 40%. Productivity increases by 15% and production costs decrease by 13%. Nevertheless, the industrialization levels in architecture and construction are still very low, appearing only in some construction elements or specific kinds of buildings.[6] While the major part of design and production is executed in large and complex sequences of activities for each case, maintaining the work's individuality and unawareness of time's development generates high product's costs and hence lower benefit to society.

This paper brings three recent architectural works of very different sizes and contexts, all of them using new digital manufacturing technologies, which reveal similar features of their production processes, namely, the Beijing Olympic Stadium, executed between 2004 and 2008 and designed by the Swiss architects Herzog and De Meuron, a rural retreat in the south of Brazil, designed by the architects of Studioparalelo and executed at the end of 2007, and a workshop with architecture students and professionals, held by the architects at the end of 2008.This paper describes their characteristics, design and execution processes and analyzes the involved activities, suggesting new relationships between design and construction. Ultimately, possible implications on the professional situation and its projections are discussed.

Beijing Olympic Stadium

Olimpijski stadion u Pekingu

The Olympic Games held for the first time in China's capital, required that the local authorities began in 2002 a large construction plan involving sports facilities and urban renewal. The development of an Olympic campus in the district of Chaoyang, southeast of the city, entailed the construction of large parks and new stadiums with high standards and public capacity, but also tight construction deadlines. Despite that, the City Planning Commission decided to face the challenge of these huge and sophisticated buildings through an international architectural contest. The main Olympic stadium required a capacity of 100 000 people, a retractable roof, a multifunctional design (which would allow different later uses) and an emphasis on sustainable aspects and advanced technology.[7] By the end of 2002, architectural firms around the world were selected, and on December 19th the same year, the contest began in two stages, culminating on April 2003 with the announcement of the elected proposal by Herzog and de Meuron's office, associated with Stefan Marbach, the artist Ai Weiwei and China Architecture Design and Research Group (CADG).

The Swiss architects Jacques Herzog and Pierre de Meuron have been characterized since the beginning of their career by a large professional capability with a particular link to art. Their buildings have a strong material expressivity, and have recently been marked with an exploration of digital design technologies. In other words, the architects combine their artistic intentions with digital manipulations.[8]

The first inspiration for the design of the Beijing Stadium was an artwork bowl carved in wood with stripes in multiple directions. So the architectural proposal evolved into a rounded volume with a structural weave that covers the tiers, creating a continuous facade and at the same time supporting the roof. What has been generated is a perimeter space embedded within an inner circulation and a monumental volume that presides over the previously open square. Its complex structure would take its time after the "bird's nest" appeal. However, none of the analogies would suggest effective possibilities to build this huge structure. The original concept was a monolithic shape and bird's nests are composed by random elements resisting shear stress by friction. So, this was an important design challenge, which lasted until the end of 2004, when the retractable roof was excluded and the number of seats was reduced to 91 000.

The final design resulted in an elliptical shape, 330 meters long, 284 meters wide and 69 meters high, allowing the vast majority of spectators to situate themselves on the axis of the ellipse and ensuring a good visibility of the field. It consisted of a geometrical volume formed basically as a toroid on the roof surface and an elliptical cone on the facades, with a low curve between both of them, developing a surface built on a total of 258 000 m^2 with six top levels and two bottoms, the ground of 20 hectares in total.[9]

The threedimensional structure design was elaborated with CATIA[10] software and analyzed with ANSYS[11] by the Finish consultant firm Tekla, including the collaboration of China Architecture Design & Research Group, Ove Arup & Partners, Hong Kong Ltd. and

6 Martinez, 1992
7 Rogers et al, 2008
8 Bruscato, 2006
9 Lerner, 2007
10 Computer Aided Three Dimensional Interactive Application, software for architectural and engineering design, by Dassault Systemes, France.
11 Software for structural analysis with finite element method, by Swanson Analysis Systems, Inc.

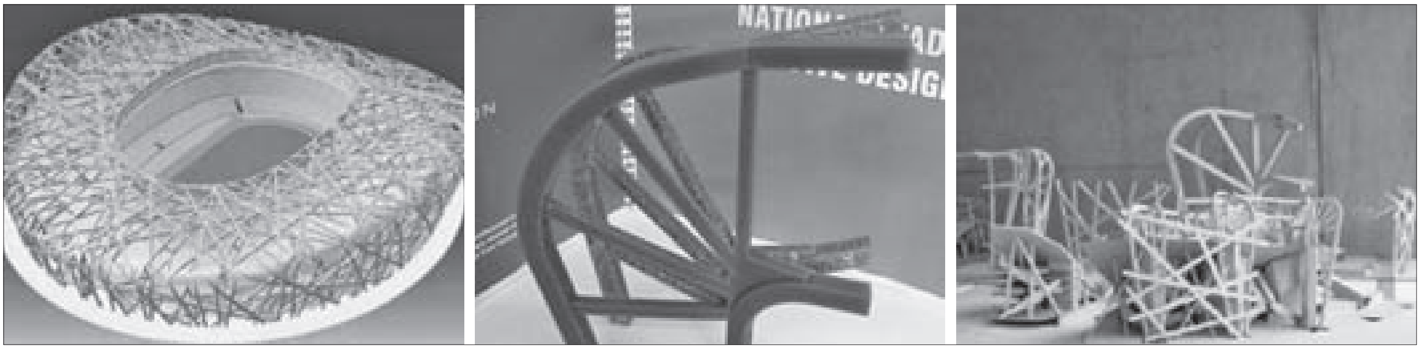


Fig. 2 Digital Design and Models of Beijing Stadium
Sl. 2. Digitalni nacrti i modeli stadiona u Pekingu

Arup Sports, from London. The result was a main reticular structure system with turrets and 24 big transversal beams with 343 meters of structural light and 38 meters distant, shaping the overall rotation and tangentially to the central opening.[12]

The turrets received two convergent beams at the same time, which compensated the stress. Considering the secondary structure for the circulation with diagonal pieces of similar dimensions and finishing, suggesting a homogeneous composition. The design of the structural elements required a detailed threedimensional modeling. Besides being a critical element to the assembly, a particularly important component was the junction between the pyramidal turrets and the beams that had a similar shape but different traces of each element. For this reason, several turret models were generated, through rapid prototyping (stereolithography), mainly to ensure the combination of structural and aesthetic requirements, with the execution process.[13] Meanwhile, several comparative analyses of environmental behavior were made.[14]

The load capacity and connections were substantially improved through the structural analysis software with a re-adjustment of the main and secondary structure. The structural elements were composed of metallic boxes developing shop drawings of each panel side for manufacturing by automated machinery.

Fig. 3 Construction Process and Final Building of Beijing Stadium
Sl. 3. Proces konstrukcije i finalna građevina stadiona u Pekingu

The mounting of elements with temporal support towers was studied, including the seismic resistance capacity during the building process, reducing the estimated steel consumption at first by 80 000 ton to a slightly more than 40 000 ton, composed by 36 km of pieces.

The on-site construction began on December 24th 2003, although the overall design was finished in November 2004, with the execution occurring in autonomous stages, although tied to contracts. In December 2005, the foundations and the reinforced concrete structures were completed. On November 2006 the metallic structure was assembled, manufactured by big steel factories, leading to a culminating general construction in December 2007. The construction was managed by National Stadium Co Ltd, a company established by public and private property shareholders.

The four years envisaged for the execution of a building of this complexity and magnitude was a significant time-limit, (especially when compared with the fourteen years needed to build Sydney's Opera House), considering the combination of several manufacturers and specialists. The two years of making designs and conducting studies also involved professionals around the world who used the newest technologies, including a straight integration between architectural design, structure and execution, and the digital information communication between different software and manufacturing equipment.

Rural Refuge in Brazil

Ruralni zbjeg u Brazilu

At the end of 2006, an advertiser commissioned a young architects' firm from Porto Alegre and Montevideo (Studioparalelo) to design a summer refuge in southern Brazil. The investor also looked forward to involve

12 Fan, 2008
13 Stacey, 2004
14 Wang, 2005

Fig. 4 Rural Refuge built in São Francisco
Sl. 4. Ruralni zbjeg sagrađen u São Franciscu

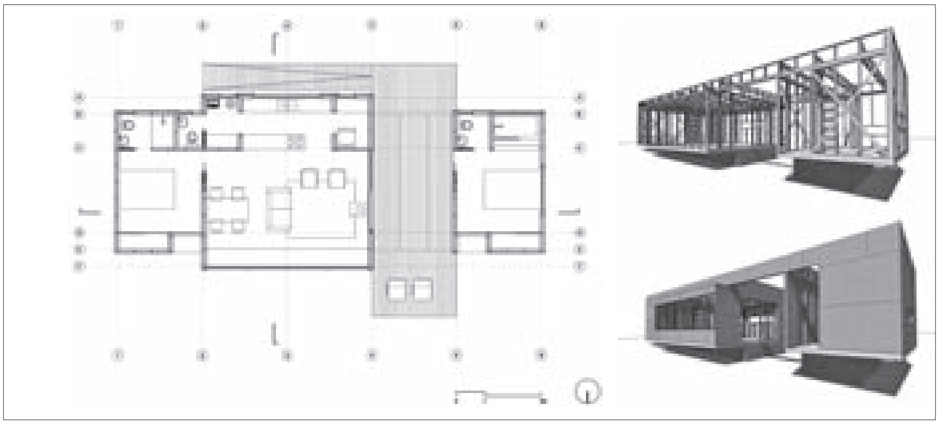
companies that were introducing new constructive products in the region, offering to promote their technical advantages in a novel design and to advertise the construction process on the web. Then, the constructive technology used on this project employed traditional materials but applied them through innovative building elements to a contemporary design. The proposal of this holiday residence, located in a forest in southern Brazil (Rio Grande do Sul) near to the city of São Francisco de Paula, was developed with certain preconditions, such as its implantation in the center of the lot with a total surface of 1 610 m^2 and a soft slope. The design proposes the house of 85 m^2 supported by a concrete slab high from the ground so not to interfere with the natural profile and avoid the rising moisture.[15]

The refuge's design program is minimal and simple, with the predominance of clear spaces and natural light, which, with the minimal intervention on the ground, highlighted a low-cost construction. These concepts determined the way the architects took while designing a dry construction linked to the atypical use of traditional materials. This design decision was based on the investigation of components used in the region, as wood and metal sheet, which were always used on houses, agricultural sheds and industrial constructions built in that region by European immigrants. They also used the old strategy of elevating the house from the floor, keeping it safe from moisture, which local Italian immigrants solved with the punch (wooden pillar). Of course there is an aesthetic consideration, based on a rigid structural logic and restrained by the adopted technology.[16]

The volumes are straightforward: two rectangular boxes of different textures that intersect each other. The bigger one, coated with a corrugated metal sheet, houses the intimate section with two bedrooms and bathrooms on opposite sides. The second, wooden box is more transparent and crosses the metal pavilion configuring the social area as well as the service one (living room, dinning and kitchen). When passing these volumes, a terrace with wooden flooring is projected out into the forest, crossing the main body of the house and serving as main access, distribution hall and sight place.

The house was thought through on the basis of the structural logic of the industrialized constructive system, with 1.20 × 1.20 m modules composed of galvanized steel bars. The wall composition consists of panels made out of plasterboard, rock wool, phenol and permeable membrane, isolating it from humidity. Only in the wooden volume, the internal coating is the same as on the exterior. Complementing the structure, a box in concrete blocks, half-buried, away in relation to the slab, forms the foundations and accommodates a small deposit at the bigger slope. The design tried to meet the program needs looking forward to delimit the built space, without camouflage mimic, but appropriating the landscape without competing with it. To develop the refuge's design and execution it was fundamental to coordinate with the supplier companies. Defining the constructive system, the structural calculation and detailing was done by the Placa Center and Formac companies. Both enterprises supplied all metallic bars and wood boards, the sliding doors sys-

Fig. 5 Plan and Construction's Model of Rural Refuge
Sl. 5. Nacrt i model konstrukcije ruralnoga zbjega



15 Basulto, 2008
16 Sayegh, 2008

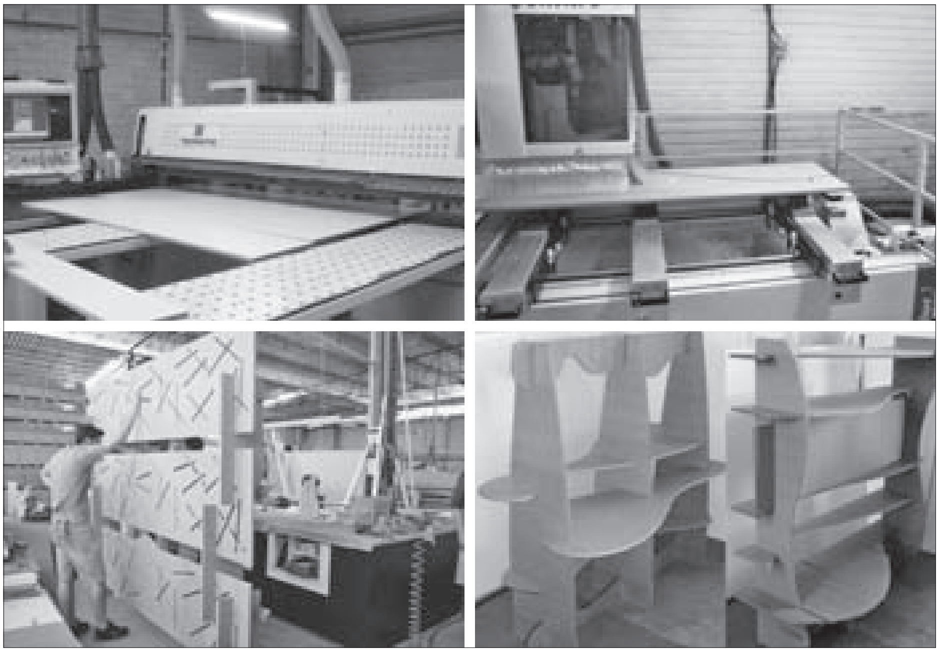
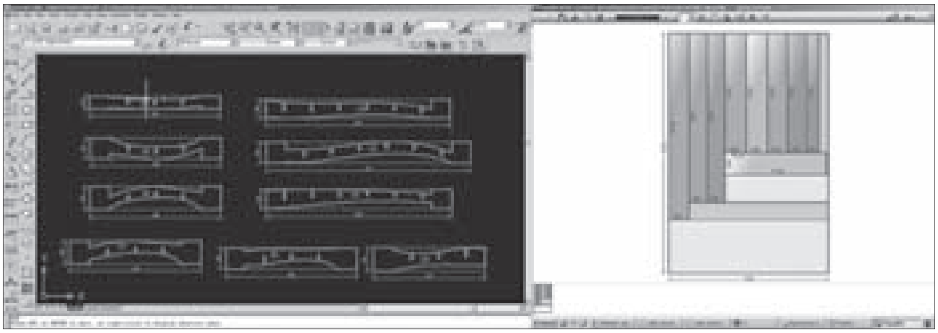


Fig. 6 Drawing of Pieces in the Workshop
Sl. 6. Crtanje komponenata tijekom radionice

Fig. 7 Manufacturing and Mounting of Elements in the Workshop
Sl. 7. Proizvodnja i postavljanje elemenata tijekom radionice



tem, divisions and roofing. They collaborated on the structural and execution analysis through automated machinery and digital plans.

A full 3D model using SketchUp[17] software was created by architects in order to explicate the details and connections of structure by describing the diverse elements and finishing. They also developed an animated sequence on different stages of execution. In addition to panel design, roof and furniture designs were also made, and the entire project finalized in mid-2007.

After that the components in an industrial structure were built according to two main aspects, that is, agility in the construction which reduces the work time in situ and allows control during the constructive process. So, executing the panels in a shed at Porto Alegre, 100 km from the work site, enabled the technical team's diary monitoring and developing without weather interruptions. Two weeks were taken to cut and mount all the structural elements (walls and roofs) and ply veneers on the smaller modules. Later, all the components were transported by truck to be assembled on the site. The total construction took 8 weeks to be concluded, including the foundations and service execution, as well as the installation of other elements, while the construction of a house in these areas normally takes five or six months.

Even with a use of a universal system, components and industrial processes, the project was expected to meet the client's needs in a specific place. However, it is possible to use this technology to produce mass houses with different models that can be adapted to the site and client's needs. In this specific case, design has a fundamental role, based on industrial conditions, to generate an innovative solution for a shorter time span than conventional processes.

Workshop on Architecture and Digital Manufacturing

Radionica arhitekture i digitalne proizvodnje

An extension course devoted to Architecture and Digital Manufacturing at the School of Architecture and Urbanism of Universidade do Vale do Rio dos Sinos (UNISINOS), São Leopoldo, Brazil, was held from November 27th to 29th 2009. The course was based on previous experiences of collaborative activities in introducing new design technologies[18] and it was developed as a practical and theoretical workshop with the duration of 21 hours. It had the support of the furniture industry Armarius and the company of wooden boards Masisa, with the participation of 22 students and graduated professionals from around Brazil.

The workshop's aim was to give an innovative vision of contemporary architecture, through international examples, new designs and manufacturing technologies. The participants attended lectures about real cases, digital modeling technologies, digital manufacturing systems and a practical exercise in four steps. The aim of the exercise was to design a wall-furniture unit in pairs of participants, followed by the selection of some of the proposals for manufacturing in groups of 5 or 6 members, where concepts and technologies previously explained in theoretical conferences were applied.

The first step of the practical work consisted in developing a design concept based on a particular perception through different senses. While traditional architecture is very vi-

17 Software for architectural modelling, property of Google, developed by @Last Software

18 Chiarella et al, 2007

sual, digital manufacturing can bring a greater sense of touch and mass and constructive components smell, so all together stimulate a more comprehensive conception of architectonic reality. Each participant was blindfolded and then asked to choose one out of ten offered scents in a reflexive and sensitive process. Later the pairs were created based on the similarity of the chosen scents and were asked to generate a graphic and written interpretation of the scent without identifying it, searching for concepts and shapes that inspired the function and shape of the wall furniture.

The second step, developed in pairs, consisted of 3D modeling inside a volume of 1.80x 0.50x1.50 meters, using the software 3D Max.[19] Aware that the digital manufacturing system later to be used allows cutting boards, the design was modeled with mounting rectangular elements or making planar sections of the total shape. Also, the structural behavior was advised, considering the estimated resistances of the boards and their connection possibilities, based on previous experiences by instructors of the workshop. Finally, the concept and design were visually presented to the group by each pair.

The third step included drawing of pieces in 2D, exporting the planar elements or traces, but also reviewing the structure and execution in the model, defining ensembles and supporting pieces. In the 2D drawing the pieces were arranged in frames according to the sizes of boards, work margins, widths and supports of machines. Four of the most complete and innovative proposals were selected by free vote and the digital plans sent to the factory by e-mail. The entire design process, analysis, detail and presentations lasted for about eight hours in total.

The technical designer from the factory converted the drawings to the software Promob,[20] arranging first the rectangular layout of the boards for a straight cutting table and then the cutting of curves and laces of each piece to a CNC[21] router. Each model was distributed in two or three boards, which were cut in about ten minutes and then the curved pieces cut in about 30 to 60 minutes in total. Meanwhile, the workshop participants visited the factory and its equipment, observing the cutting process. Later, they finished some pieces themselves (smoothing the curves or missing laces), mounted the elements and found some defects which were quickly replenished with newly cut pieces. It all together lasted for about one hour. Finally, they made a photograph of the mounted pieces and the site of the wall furniture generating a visual presentation, and developing a package for the pieces. It was made so that they can be taken out and installed at the university campus by some of the participants where they were already being put to the envisaged use.

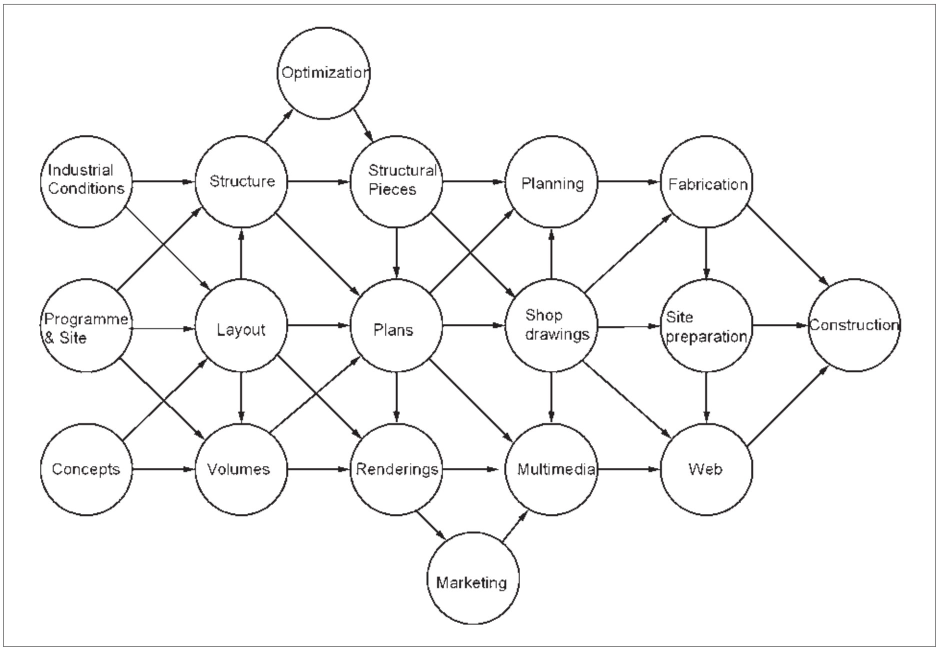


Fig. 8 Schema of design's tasks in the three cases studied

Sl. 8. Shema uloge nacrta u trima analiziranim radovima

This activity was described by the participants as very motivating and enlightening of new industrial possibilities of designing and construction, which was revealed through the strong personal involvement in the modeling and mounting process. Also, new perspectives for product lines were suggested to the factory. This unique university-industry collaboration experience in a work area related to architecture, which is usually separated, generated an important reflection in the participants and involved entities, as the real scale constructive elements and effective performance, in a much shorter time thanks to design technologies and applied manufacturing.

Analysis

Analiza

These three experiences, in spite of the enormous differences of sizes between the built works, show some singular similarities in the process. These three examples, in very different situations, expose a large effort of designing and planning in relation to execution. Normally it is considered that design and pre-

19 Software for three-dimensional modelling by Autodesk Media&Entertainment (previously Discreet Inc.)

20 Software for modelling and manufacturing of furniture developed by PROCAD, Brazil

21 Computer-Numeric Controlled machine liminary management could last an equivalent of one fourth or one third of the time necessary for the construction of a building (and around one twentieth in terms of budget), which can range from a couple of months to one year or more relative to the size of the work and function of the building.[22] However in the cases reviewed, the previous processes lasted more in relation to the duration of construction. The Beijing Stadium took two full years to be designed and planned, in a particularly fast track and overlapping with the four-year long execution, that is, one half of the construction time. The design of the refuge took more than six months, but only two months of manufacturing and construction, which makes planning three times longer. During the workshop, nearly ten hours were destined for the design, but for manufacturing and total assembly of the elements it took less than two hours which is a ratio of one to five.

This relationship might be established by the complexity and novelty of the involved processes but, at the same time, the reduction of the site work is visible. It means that a larger amount (and variety) of tasks were assumed by architects, engineers and technicians involved in designing and planning. That should also presuppose some cutback of site workers' time, in relation to traditional ways of building. Likewise it must be considered that it accomplishes more technological activities, such that involve a more qualified staff than the ones that get eventually reduced. It means that more people with lower wages are laid off and the commitment of smaller but better paid personnel increases, changing the wage and the staff arrangement, but maintaining competitive results. Considering that the assignments expanded are more technical, creative and efficient, it is probable that they will be assumed by professionals or skilful operators. With higher education (particularly in developing countries), much could be made by architects or building engineers. However, a more productive vision and aesthetic, industrial and constructive skills will be required to support the professional growth but with an important diversification and modification of the labor approach.

Besides, the designing process of the three cases shows experimentation, an increase of activities with parallel works and simultaneous interests that stress some tasks more than other, though all of them interact and connect to each other establishing a "wide" process, diverse sequence of activities related between them, which can be developed by the same staff, according to the design's magnitude, but in big works several specializations are necessary.

In addition to the main design flow, originated by the building program in a determined place, the industrial conditions are presented and, also, public projections that require specific requirements of the design. Though, clearly, there were always technical requirements of the constructive elements, in this case building elements arise with more concrete and specialized features, oriented to a bigger work sets. Established were a design flow, components analysis and execution, but they clearly interact (collect and provide information) with the main architectural design. The three cases also included "external advice" for a structural improvement of design which expresses the need or the possibility for an independent analysis of this aspect. On the other hand, conceptual requirements belonging to the institutional client are recognized and they are fed with design's features a bit far from the central and technical development, producing independent diffusion media.

This distribution of activities evidently requires a more variable structure, flexible professionals and a strong computational support, with intense data flows and the integrity of design's development. That's not an easy work on large buildings, but increasingly necessary. This assignment repertoire must be more characterized, thoroughly, to accurately identify new tasks and processes involved. However, some features have been suggested on the three experiences studied.

Conclusion

Zaključak

Architectural activity seems to hardly value temporal aspects. However these conditions are substantial to its development, execution and building occupation. Also, the reduction of time in these processes is what has supported the industrial and computational developments that strongly contribute to contemporary society. Three cases of different sizes were analyzed in this paper, with a heavy use of digital design and manufacturing technologies – the Beijing Olympic Stadium, a rural refuge in southern Brazil and a university workshop. The activities and processes were described, so as to show similarities in some aspects. In particular, the duration of design and execution assignments, which, despite very different extensions, reveal a proportional change between them that are different from the traditional process. Also designing and planning seem as a

22 Martin et al, 2006

23 Male-Alemany, Sousa, 2003

larger variety of tasks, which constitutes a process with a network structure, already suggested by other authors.[23] They reveal a particular involvement of industrial and promotional conditions, which establish parallel flow of activities, strongly linked with the central development of design and construction. After that, implications of labor arrangements were discussed, suggesting a development of the architect's role towards a greater diversity of technical skills in manufacturing and building management, though it implies a reduction of site workers, but framed in industrial progress. The cases show an important link between the conceptual, functional, promotional and productive construction, such that can be developed with an architectural perspective. This analysis of production time and process in three architectural works reveals essentially a relationship to new work culture and age of production, suggesting a more exhaustive study and formulation of design and execution of buildings, and more collective contexts, which can define productive possibilities of architecture.

[Lektura: Željka Miklošević, prof.]

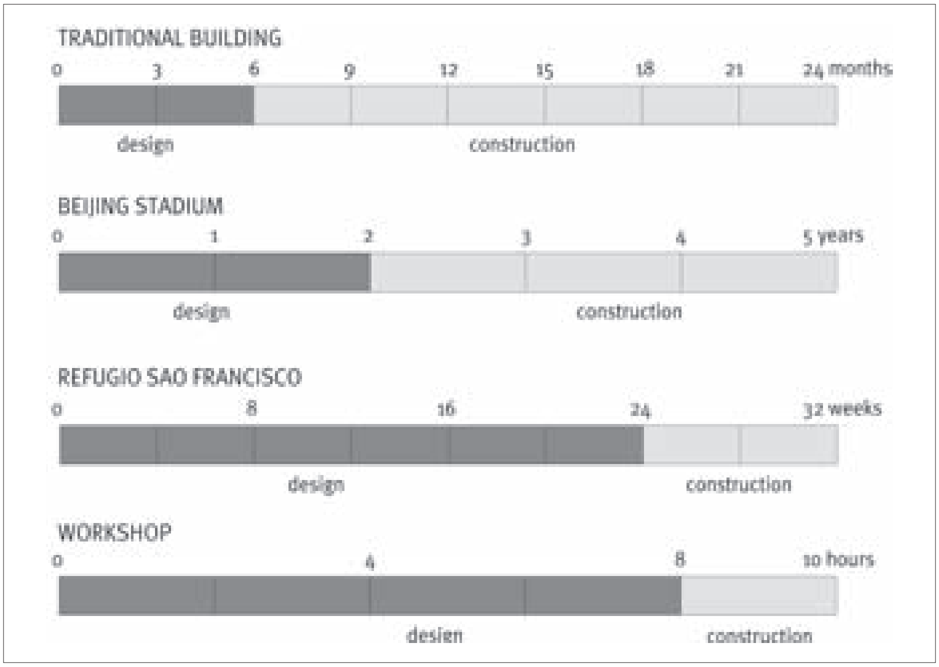


Fig. 9 Comparison of time proportions between design and construction in the cases studied

Sl. 9. Usporedba u količini vremena projektiranja i konstruiranja u analiziranim radovima

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Sources

Izvori

Illustration Sources

Izvori ilustracija

Fig. 1, 2, 3	http://www.n-s.cn/en/
Fig. 4, 5	Studioparalelo, 2007.
Fig. 7	Drawing by authors.
Fig. 6	Photo by authors.
Fig. 8, 9	Diagrams by authors.

Summary

Sažetak

Tri recentna iskustva na području arhitekture i digitalne proizvodnje

U arhitektonskim djelima vrijeme se rijetko kada uzima u obzir iako uvelike utječe na projektiranje i konstruiranje građevina, kao i na njihove kasnije uporabe. Industrija i digitalna tehnologija omogućuju različitu uštedu vremena u tim procesima, što može pridonijeti ili promijeniti neke uvjete suvremene građevne izvedbe.

Članak govori o trima recentnim arhitektonskim primjerima vrlo različitim po veličini i kontekstu, no svaki od njih koristi nove tehnologije digitalne proizvodnje, pri čemu se otkrivaju slična obilježja u njihovim procesima proizvodnje – olimpijski stadion u Pekingu, izgrađen između 2004. i 2008. godine, koji su projektirali švicarski arhitekti Herzog i De Meuron; zatim ruralni zbjeg u južnom Brazilu, sagrađen krajem 2007. godine, koji su projektirali arhitekti tvrtke Studioparalelo, te radionica sa studentima arhitekture i profesionalcima, koja se održala krajem 2008. godine. Članak opisuje neke karakteristike procesa projektiranja i izvedbe u tri navedena slučaja. Olimpijski stadion u Pekingu zamišljen je s kapacitetom od 100 000 ljudi te s pomičnim krovom, multifunkcionalnim dizajnom i naglaskom na održive aspekte i modernu tehnologiju. Arhitektonski projekt za stadion razvijen je u obliku zaokruženog volumena sa strukturalnom mrežom koja prekriva katove stvarajući kontinuiranu fasadu, a istovremeno podupirući krov. Kompleksna struktura ovoga projekta nastala je prema modelu ptičjega gnijezda. Projekt se zasniva na glavnom mrežnom sustavu s tornjićima i 24 velike, 38 m duge transverzalne grede, koji služe ujedno i kao struktura i kao fasada. Strukturalni se elementi sastoje od metalnih kutija, od kojih je svaka stranica prvo izvedena u crtežu kako bi poslije dobila svoj oblik u automatskom procesu izrade. Vrijeme je gradnje u slučaju građevine ovakve kompleksnosti i veličine svedena na četiri godine te je uključivala suradnju nekoliko proizvođača i specijalista za gradnju. Dvije godine, koliko je bilo potrebno da se finaliziraju nacrti i studije, također su uključivale i suradnju s profesionalcima diljem svijeta sa znanjima o najnovijoj tehnologiji. Cjelokupan pothvat ujedinio je arhitektonski nacrt, strukturu i izvedbu, digitalne informacije koje su kolale između različitih *softwarea* te produkcijsku opremu, zajedno s javnom promocijom građevine u medijima. Projekt zbjega jednostavan je i minimalistički, s industrijski proizvedenom konstrukcijom koja se sastoji od galvaniziranih čeličnih šipaka. Potpuni 3D model načinili su arhitekti kako bi izložili detalje i veze strukture te opisali različite elemente i završne radove. Također su razvili animirani niz različitih faza izvedbe. Planiranje i projektiranje trajalo je gotovo pola godine, a za to vrijeme također su se obavljali dogovori s dobavljačima, tehničkim službama i radio se *web site* kako bi se promovirala inovativna uporaba materijala. No cjelokupan je proces izvedbe trajao samo 8 tjedana, što je jedna trećina vremena koje je inače potrebno za gradnju tih tipova kuća u regiji. Projektiranje je imalo ključnu ulogu, budući da se temeljilo na industrijskim uvjetima u pronalaženju pravog rješenja i kratkoći vremena u usporedbi s konvencionalnim postupcima. Radionica, u kojoj su sudjelovali i studenti i profesionalci, trajala je tri dana, tijekom kojih su sudionici projektirali i izveli pojedine elemente namještaja. Dva su dana radili u računalnom laboratoriju na Sveučilištu izrađujući digitalne 3D modele i crteže za izradu, te jedan dan u tvornici s proizvodnom mašinerijom kako bi u nekoliko sati izradili konstrukcije u stvarnoj veličini. Sudionici su za te aktivnosti rekli da su ih motivirale i otvorile nov pogled na mogućnosti industrijskog dizajna i izvedbe, a što su iskusili kroz osobni angažman tijekom postupka oblikovanja i postavljanja dijelova namještaja. Nadalje, sama je tvornica od sudionika dobila sugestije o novim perspektivama za svoje linije proizvoda.

Ovo jedinstveno iskustvo suradnje Sveučilišta i industrije na polju arhitekture, što se inače ne događa često, generiralo je značajne pomake u razmišljanjima kod sudionika i uključenih strana s obzirom na konstruktivne elemente u realnoj veličini i efektivnu izvedbu u mnogo kraćem vremenskom roku, zahvaljujući tehnologiji projektiranja i dizajniranja te proizvodnji. Unatoč golemim razlikama u veličini između spomenutih arhitektonskih djela, ova tri primjera demonstriraju velike napore uložene u planiranje i projektiranje u usporedbi s izvedbom. To znači da su arhitekti, inženjeri i tehničari bili zaduženi za velik broj zadataka koji se odnosio na projektiranje i planiranje. To također znači da se skratilo vrijeme rada radnicima na gradilištu, u usporedbi s tradicionalnim načinima gradnje. Treba se naglasiti i to da su projekti uključivali tehničke aktivnosti koje su zahtijevale kvalificiranije osoblje, a to je kao rezultat imalo promjenu u rasporedu i plaćanju osoblja, no uz održavanje kompetitivnih rezultata. No, svakako, bilo je potrebno razviti produktivniju viziju te estetske, industrijske i konstruktivne vještine koje bi potpomogle profesionalan rast, sa značajnim obogaćenjem proizvodnje i modifikacijom pristupa radu. Osim toga, ono što je prikazano u trima spomenutim projektima jest eksperimentiranje i povećani broj aktivnosti, s paralelnim procesima i simultanim interesima koji ističu neke radnje više od drugih, iako sve one međusobno djeluju i povezane su na način da tvore raznolik niz međusobno povezanih aktivnosti. Slične projekte može izraditi i opće osoblje, ovisno o veličini projekta, no u opsežnijim radovima specijalizirane su osobe neophodne.

Očito je da je za distribuciju aktivnosti potrebna varijabilna struktura, fleksibilni profesionalci i snažna računarska potpora, s velikim protokom informacija i integritetom projektnog postupka. Smanjenje vremena u ovim je procesima uporište industrijskog i računarskog razvoja koji uvelike pridonose suvremenom društvu. To ukazuje na činjenicu da nove tehnologije mijenjaju vremenske i djelatne odnose između projektiranja i izvedbe.

Daljnje bi se istraživanje trebalo provesti na novim tehnologijama industrijalizacije gradnje i srodnim projektantskim aktivnostima, reorganizacijom procesa projektiranja i izvedbe te njihova utjecaja na tržište rada.

Rodrigo García Alvarado
Underlea Miotto Bruscato

Biographies

Biografije

Rodrigo García Alvarado has a Ph.D. in architecture from Universidad Politecnica de Catalunya, Spain (2005). He works on digital media in architecture, in particular 3D modeling, animation and digital fabrication. Currently he is head of Ph.D. programme in Architecture and Urbanism of Universidad del Bio-Bio, Concepcion, Chile.

Underlea Miotto Bruscato has a Ph.D. in architecture from Universidad Politecnica de Catalunya, Spain (2005). She works on digital design and contemporary architecture, cultural management and heritage. Currently she teaches at Universidad do Vale do Rio Sinos, Sao Leopoldo, Brasil and Universidad de La Salle, Canoas, Brasil.

Rodrigo García Alvarado doktorirao je na Universidad Politecnica de Catalunya u Španjolskoj (2005.). Područje djelovanja su mu digitalni mediji u arhitekturi, posebno 3D oblikovanje, animacija i digitalna izrada. Trenutačno je voditelj doktorskog programa Arhitektura i urbanizam na Universidad del Bio-Bio, Concepcion u Čileu.

Underlea Miotto Bruscato doktorirala je arhitekturu na Universidad Politecnica de Catalunya u Španjolskoj (2005.). Trenutačno drži kolegij na magistarskom programu Memorija i kultura na Universidad do Vale do Rio Sinos, Sao Leopoldo u Brazilu i Universidad de La Salle, Canoas, također u Brazilu.