ENGLISH VERSION

Projections of 3D-printed construction in Chile
Proyecciones de la construcción impresa en 3D en Chile

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Abstract

3D printed construction has recently emerged as a new building technology, with various experiences disseminated around the world. This paper reviews existing documents and examples of this technology to characterize its potential projections, particularly those oriented towards improving productivity and sustainability of construction in Chile. Scientific and conference papers, technical reports and thesis are analyzed, as well as the dissemination of executed constructions on the Internet, in order to understand the developments and attributes of this building system. Also, the current conditions and challenges of the construction sector in Chile are summarized, and consultations to stakeholders about their knowledge and expectations of this technology are included. The results from this review highlight the trending topics in different countries, which mostly consist of experimental houses built with cementitious mixes deposited with cranes or robots. According to documents and practitioners from Chile, the interest of applying this technology in our country could be mainly focused on the industrialization of residential envelopes with high thermal and seismic capacities.

Keywords: *3D-Printed Construction, Digital Fabrication, Industrialization, Robotic Construction, Chile*

Resumen

La construcción impresa en 3D ha surgido recientemente como una nueva tecnología constructiva, a través de experiencias diseminadas alrededor del mundo. Este artículo revisa la documentación existente y los ejemplos de esta tecnología para caracterizar sus proyecciones potenciales, en particular, aquellas orientadas a mejorar la productividad y sustentabilidad de la construcción en Chile. Artículos científicos, de conferencias, informes técnicos y tesis son analizados, junto con difusión en internet de construcciones ejecutadas, para comprender los desarrollos y atributos de este sistema constructivo. Además, se resumen las condiciones actuales y los desafíos de la construcción en Chile, y se realizan consultas a participantes del sector sobre el conocimiento y las expectativas de esta tecnología. Los resultados de esta revisión destacan la tendencia en diferentes países, que consisten, principalmente, en casas hechas con mezclas cementosas depositadas con grúas o robots. De acuerdo con la documentación y los profesionales en Chile, el interés de aplicación de esta tecnología en nuestro país podría orientarse, principalmente, a la industrialización de envolventes con altas capacidades térmicas y sísmicas para viviendas.

Palabras clave: Construcción Impresa en 3D, Fabricación Digital, Industrialización, Construcción Automatizada, Chile

1. Introduction

3D printed construction is a new building technology that has gained importance in recent years thanks to the dissemination of experiences carried out in worldwide, such as those presented by (Ghaffar et al., 2018); (Ma, 2018); (Perkins and Skitmore, 2015). These experiences show the use of different automated equipment in the execution of construction elements or small buildings by means of the additive manufacturing process through material extrusion. Both executors and documents mention that this technology has different potential benefits for the construction industry, in terms of reducing time and costs and fostering a personalized industrialization.

Chile is an emerging Latin America country, with increasing and exemplary construction industry in the continent (Prom Peru, 2015). However, significant deficiencies have been identified with regard to the energy performance of existing buildings, quality of urban air and environmental impact of construction processes (CDT, 2010); (CNE, 2017), as well as work performance stagnation, fragmentation of activities, and a low level of digital management and industrialization (CORFO and PMG, 2016); (Loyola and López, 2018).

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The national institutions of the construction sector, with the support of commercial and academic organizations, have assumed the need to improve sustainability and productivity. Recently, the Chilean government promoted a public-private plan aimed at introducing new technologies and developments in the construction industry, particularly by boosting process automation (CORFO, 2014). Thus, new systems and potential applications must be identified and developed, in accordance with the technological progress and local requirements and interests. With this purpose in mind, this paper seeks to identify the current state of 3D printed construction and, especially, its possibilities and potential introduction in Chile, in order to establish a link between achieved developments and the conditions of the national construction industry, thus allowing the identification of specific developments for the near future. Therefore, the present document makes a review of papers addressing this topic and initial experiences throughout the world, as well as a brief analysis of the national industry and the perception of stakeholders.

2. State of the art

Various publications reviewing the initiatives using 3D printed construction identify different systems, such as (Lim et al., 2012), who report three techniques (concrete impression, contour crafting and D-Shape printing), which can be applied in the fields of architecture, art or public works. In general, these techniques consist in the deposition of vertically-added horizontal filaments (Figure 1). (Doely, 2014) presents the use of different 3D printed construction technologies, describes certain experiences, makes comments about the possible benefits of generating non-traditional shapes and reducing the execution times and costs, and also discusses risks and challenges of losing employments. (Malé Alemany, 2016) reviews several additive manufacturing procedures for making architectural elements, thereby highlighting their potential for free-form designs, variability, personalization, complexity, optimization, no assembly requirements, and the use of different printing materials. (Perkins and Skitmore, 2015) also present the three main processes mentioned above, and review the possible advantages and limitations regarding waste reduction, digital integration, labor reduction, construction speed, industrialization and costs. (Bos et al., 2016) analyze experiences and the technological characteristics of this technology, recognizing different strategies and their consequences, such as the optimization of the production or performance, either on site or at the factory.

Figure 1. *3D printed construction technologies (above: concrete printing; below left: contour crafting; below right: D-Shape printing. Source: (Ghaffar et al., 2018) and (Ma et al., 2018)*

Other researchers, such as (Hager et al., 2016), name the working conditions and discuss possible advantages of using this technology in terms of low costs, environment compatibility, waste reduction, workplace accidents and working time. (Labonnote, 2016) offer a review of 165 scientific papers dealing with 3D printed construction, which include experiments with materials, various technologies (cranes, cable-suspended robots, swarm robotics, robots, folding robots), design proposals for buildings and applications, thereby making a difference between using them in risky or regular construction environments. Their review also summarizes a number of experiences and requirements regarding architectural design processes using this technology. (Wangler et al., 2016) focus on the description of additive manufacturing with concrete and robotic arms, and identify technical advantages and challenges thereof. (Anjum, 2017) study the possibilities of 3D printed construction in India through a survey to 186 professionals, which identifies increasing knowledge and large expectations as the main advantages, and scarce development of regulations and technical materials as the main disadvantage. (Duballet et al., 2017) classify 3D printing systems according to their size and working conditions, including large crane systems and robotic arms for work on and off site.

On the other hand, recent documents point at possible 3D printed construction applications, such as (Mathur, 2016), who suggests advantages related to costs, labor force, productivity, safety and combination of tasks; and also proposes them for the production of low-cost and emergency housing in large developing countries. (Tay et al., 2017) review more than 400 papers dealing with different topics referring to the construction industrialization, and detail techniques and challenges of 3D printing of building components, particularly the development of printing materials and the incorporation of reinforcements. (Al Jaasmi et al., 2018) analyze several procedures, and identify material requirements and limitations for printing construction elements. (Bogue, 2018) presents various 3D printing technologies and highlights their potential contributions to the productivity of construction processes. (Delgado Camacho et al., 2018) notice the challenges and potential benefits in the development of materials and the optimized design of construction elements. (Ma et al., 2018) discuss the possible advantages of 3D printed construction (flexibility, social impact, and costs), technological challenges (equipment, materials, reinforcement, coordination, evaluation) and applications (diversity of materials, irregular shapes, BIM integration, and planetary construction). (Álvarez Elipe and Anaya, 2018) stress the significance of new construction technologies for the architecture. In general, these works mention different systems and potential advantages, showing the emerging development of this technology.

3. Methodology

According to the aforementioned studies, this review analyzes 3D printed construction technology and its possible projections in Chile along two main lines: a review of the scientific literature and international practical experiences, and the identification of local conditions and expectations, based on data observed at national level, presentations and information activities related to this technology, as well as surveys applied to the participants of these activities.

To begin with, an exhaustive number of scientific papers was collected from global databases, and practical experiences related to this technology were identified on the Internet and professional dissemination media. The compilation of scientific documents was based on the review of indexes and journals addressing this subject, together with conferences, technical reports and published postgraduate thesis. Special attention was given to high impact journals, such as "Automation in Construction", and symposiums like ISARC, organized by the International Association for Automation and Robotics in Construction (IAARC); FABRICATE, dedicated to digital manufacturing in architecture, which was held in 2011, 2014 and 2017; and Robots in Architecture, organized in 2012, 2014 and 2018. The websites of events focused on 3D printed construction, recently held in Denmark, Australia and Singapore, were also revised, although no associated publications were produced. The texts reviewed were classified by publishing date, type of document, affiliation country of the first author, subject and technology, the last two showing the greatest variability among all publications. Moreover, these contents were revised with the aim of searching further characteristics, similarities and possible alignments with local interests or specific characteristics of the Chilean construction industry.

With regard to worldwide practical experiences, searches using "3D printed construction" and similar terms led to sites reporting the direct execution of printed construction elements in different countries. Only direct sources presenting graphical evidence of complete components were considered, excluding the theoretical presentations. Totally executed buildings, organizations and facilities that have produced elements were recorded, thereby

identifying their authors or participants, institutions, location, execution year, technology and materials used. However, it was possible to observe that most of these experiences offered limited descriptions of the equipment involved and resources used, in order to protect patented developments and future commercial opportunities.

Subsequently, while focused on the review of the current situation of the construction industry in Chile, concerning the 3D printed construction, recent reports and statements of public programs were collected, together with private studies and general statistics. Likewise, the national conditions and expectations related to the introduction of new technologies were also identified.

With the purpose of projecting specific interests in the country regarding this technology, the authors participated in conferences to introduce the 3D printed construction in three national and international events (Expohormigón Congress, BIM-Chile Conference, and Conference of Latin American Faculties of Architecture) during the second semester of 2018. Furthermore, technical notes were sent to the general and sectorial press, and a workshop of 3D printed construction was organized on January 2019, including a conference and round table with the developers of the first printed house in Spain, and other presentations, visits to laboratories and work meetings. The activities were disseminated in professional and academic media, and a survey was applied during the registration process, which included the identification of the work area and the functions performed by the participant, previous knowledge of this technology, perception of different types of equipment, and possible benefits and applications. Various options were proposed in the responses to each question, which were defined according to the bibliographic review, and a blank space was provided for free answers. Moreover, the comments expressed during the activities were collected and analyzed.

4. Results

4.1 Publications

The review of scientific papers addressing the 3D printed construction allowed identifying 144 documents specifically dedicated to the analysis of this technology and the presentation of experiences and assessments. According to their publishing dates, an increasing research activity on the matter was detected, with 84% published in the last five years. These papers were written mainly by researchers of universities located in the United States (28%), United Kingdom (10%), and other 22 countries, mostly in Europe and Asia. Considering the main topics of the studies, they are focused on describing specific activities (25%) and other wide-ranging studies (22%) mentioning different experiences and discussing the potentials of this technology. The review of specific processes (21%) or materials used (15%) are also frequent subjects, while equipment, printed elements, and industrial applications receive less attention. The review of scientific papers addressing the 3D printed construction allowed identifying 144 documents specifically dedicated to the analysis of this technology and the presentation of experiences and assessments. According to their publishing dates, an increasing research activity on the matter was detected, with 84% published in the last five years. These papers were written mainly by researchers of universities located in the United States (28%), United Kingdom (10%), and other 22 countries, mostly in Europe and Asia. Considering the main topics of the studies, they are focused on describing specific activities (25%) and other wide-ranging studies (22%) mentioning different experiences and discussing the potentials of this technology. The review of specific processes (21%) or materials used (15%) are also frequent subjects, while equipment, printed elements, and industrial applications receive less attention.

With regard to printing technologies, most studies describe material deposition processes with robotic systems (33%) or supported by gantries (15%), while the remaining ones describe other configurations, such as cable-suspended robots or multiple robot systems. Finally, 53% correspond to papers published in indexed journals, where "Automation in Construction" is highlighted as the main journal contributing to this subject, and 45% of the documents are presented in conferences, especially ISARC and "Robots in Architecture", while the remaining percentage corresponds to postgraduate thesis and technical reports, as can be seen in (Figure 2).

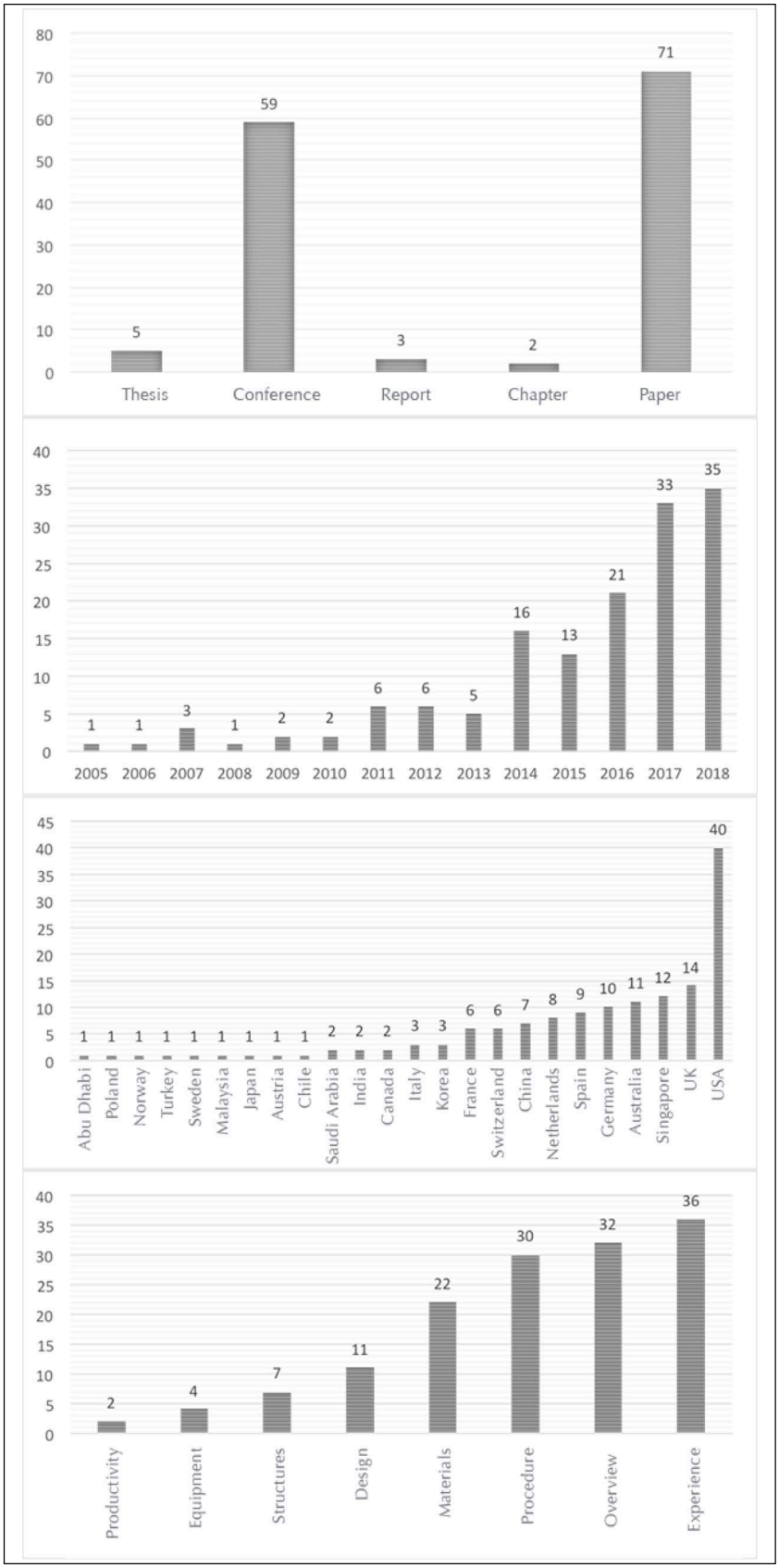

Figure 2. *Number of publications dealing with 3D printed construction (First: by type; Second: by year; Third: by country; Fourth: by subject). Source: Self-prepared*

4.2 Cases

During the search for executed buildings, 68 experiences were identified, mainly through the Internet, offering graphic evidences and texts describing the execution of construction elements or completed buildings, using automated printing systems. According to the recorded categories, most known experiences are located in China (23) or the United States (11), and the rest in other countries, mainly European ones. Most projects have been developed by private entrepreneurs and others by university researchers with the support of large construction companies or national R+D programs. These activities are commonly presented on websites and press reports, as initial experiences or first 3D printed constructions in the region, with the aim of highlighting the potential benefits of this technology and extend their scope of application. Among the identified experiences, there is a small emergency shelter executed in Milano in 2010 by the D-Shape company; various construction elements developed with different technologies by IAAC in Barcelona; a canal house in Amsterdam in 2015; a hotel in the Philippines and an office in Dubai in 2016, both built by the US company Total Kustom; a house in Russia by Apis-Cor in 2017; an emergency house in Austin, Texas, by the ICON company; a highly energy efficient house in Nantes by the Batiprint company in collaboration with local universities; and the first house printed in Spain by Be More 3D in 2018.

A total of seven initiatives were recorded in Latin America, four of them located in Chile and the remaining three in other countries: one led by the construction company Conconcreto in Colombia, which built a house with parts prefabricated with 3D printed concrete; a further experience of entrepreneurs associated to the Federal University of Rio Grande do Norte in Brazil; and another one in the National University of Cordoba in Argentina (Figure 3). In Chile, the identified experiences include a large company of prefab concrete panels using automated processes, which declared they "printed houses", although the execution is mainly manual on site, and the production of small parts with 3D printers or robotic arms by researchers or students of the Universidad de Chile in Santiago, the Universidad Técnica Federico Santa María in Valparaíso and the Universidad del Bío-Bío in Concepción (Figure 4).

The vast majority of these activities have been carried out in the last four years, although the chronological records vary (Figure 5). From the total, 65% refers to complete buildings and the rest are individual parts or furniture. Most executed constructions combine printed elements with other conventional components or do not detail the manufactured parts. From the identified cases of complete buildings, 24 refer to homes, 9 to exhibition pavilions and 11 to buildings for other purposes. 66% of the initiatives have declared to use crane systems and 18% use robotic arms, while the rest uses other systems or do not declare them. In relation to the materials, the vast majority has applied cementitious mixes, and only in three cases other materials have been used. Most of the executed buildings are experimental ones, for demonstration, and only a few of them have been commissioned or occupied afterwards.

The WinSun company, in Shanghai, affirms that they have built fifteen buildings with 3D printing technologies, a number of parts for different constructions (housing project or urban furniture), while others correspond to buildings with several floors. However, they do not detail the executed components nor the processes used. The companies Cybe (Netherlands), ApisCor (from Russia, also located in the USA), Printhuset (Denmark, currently part of COBOD), and the US Army Corps of Engineers declare buildings made in different locations, as well as the commercialization of buildings, equipment and/or mixes. Additionally, several institutions have made parts for NASA contests regarding extraterrestrial construction. There is a wide range of executed buildings, generally small (approximately 50 m2), ranch-style constructions (one floor), with certain common characteristics, like the use of 3D printing, mainly for walls, with rounded corners and coarse texture, which sometimes is covered and complemented with elements such as doors, windows, basic amenities and different types of roofs. Occasionally, these constructions use prefab printed components that, eventually, are turned around to assemble them vertically on site. Some executed parts are declared isolated construction elements, but their applications or technical details are not specified.

Figure 3. *3D printed construction experiences in Latin America and Spain (top left: 3D housing construction, Brazil; top right: Conconcreto, Colombia; below left: HausDrucker, Argentina; below right: Be More 3D, Spain). Source: the following websites: (https://www.facebook.com/pages/3D-Home-Construction https://conconcreto.com/impresora-3d/ https://www.youtube.com/watch?v=AStwJgs7jKw, https://bemore3d.com/)*

Figure 4. *3D printed construction experiences in Chile (top left: Baumax; top right: Universidad Técnica Federico Santa María; below left: Universidad de Chile; below right: Universidad del Bío-Bío. Source: the following websites: (http://www.cchc.cl/uploads/evento/archivos/1600_a_1630_Pablo_Kuhlenthal_-_BAUMAX_-_Construccion_robotizada_en_hormigon.pdf http://arquitectura.usm.cl/nuestro-departamento-realiza-primer-experimento-en-chile-de-construccion-impresa-utilizando-robot-industrial http://www.uchile.cl/noticias/144274/estudiantes-crean-prototipo-de-impresora-3d-de-concreto http://noticias.ubiobio.cl/2018/10/31/alumnos-ubb-ejecutan-primer-muro-impreso-en-3d-del-pais/)*

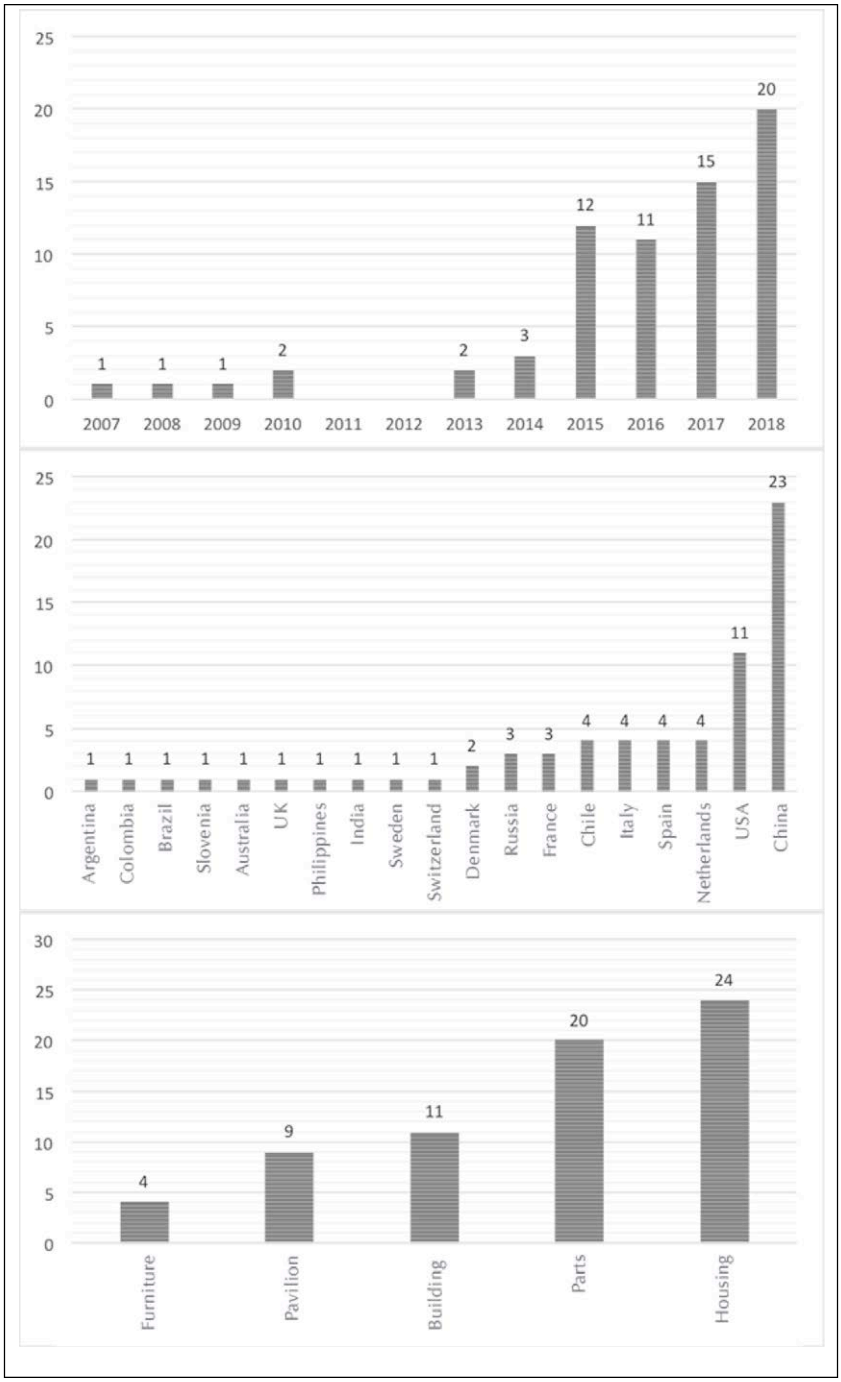

Figure 5. *Case review (top: by year; center: by country; below: by subject).*
Source: Self-prepared

Certain differences found between the activities described in scientific papers and the collected experiences, should be mentioned. The main authors of the publications come from a wider range of countries than the practical cases, which are more concentrated in Asia and Europe. Additionally, documents generally mention the manufacture of minor elements and the use of robotic printing systems, while practical cases present more developments of complete constructions printed with gantries, thereby indicating that the use of gantry systems is easier (or more practical) to implement on site than those based on robotic arms.

4.3 Construction Industry

Concerning the review of the construction industry in Chile, it should first be noted that the country is characterized by its location on the south west border of Latin America, and a milder climate than the rest of the

countries in the region. It has shown a great political stability in the past four decades, which has generated a continuous economic growth for its relatively small population (currently around 17 million). The country has been recognized for its exemplary economic development, despite its great social differences and weak domestic production. The early deregulation and open trade practices with global markets since 1980 has produced a profound economic transformation, mainly by increasing the services and export of basic products, mostly from the mining, fishing, agricultural and forestry industries.

The construction sector in Chile has played an important role in the country's development of the past decades, particularly in the implementation of different housing and infrastructure programs, together with private initiatives and recent actions for improving the sustainability and industrialization. Currently, the Chilean construction industry accounts for approximately 8% of the employments and the gross domestic product, with an annual amount of nearly US$37 billion, from which 35% corresponds to buildings (CChC, 2018). Housing programs have generated a variety of financial instruments, thus encouraging a large participation from construction companies. These initiatives have allowed covering a wide-ranging housing demand by building 150,000 units per year (INE, 2018). The public and private infrastructure has also been led by the combination of state efforts and ongoing programs for civil works, educational institutions, and hospitals.

With regard to buildings, the predominating material is concrete (53%), with approximately 10,000,000 m2 per year (INE, 2018), in monolithic structures, including beams, columns, foundations and floors reinforced with steel bars, due to the seismic conditions of the country. The structure of the buildings involves around 43% of the budget in high-rise buildings and 30% in low-rise ones (CChC, 2018). The environmental impact of the construction in Chile is larger than the operation of the buildings, followed by the energy contained in the materials, where structural products represent nearly 80%, while the execution is reduced (Muñoz et al., 2012). The occupation of buildings consumes approximately 25% of the national energy and generates 35% of the emissions and residues (20 million tons of CO2 per year). Specifically, housing has a high operational consumption (approximately 150 kWh/m2 per year), given the heating demand as a consequence of the low thermal performance and infiltrations of vertical areas (CDT, 2010; CNE, 2017). The productivity of the national construction sector is estimated around US$35,000 annually per worker (equivalent to 50% of the productivity of the same sector in the United States), with no growth in the last two decades, while other sectors have grown 1.7% per year. This deficiency is attributed to the lack of training, standardization, planning and integration of the sector, in addition to low investment on research and innovation, with a reduced use of digital technologies, prefabrication and renewable energies.

Thus, national goals have been proposed, including a 20% cost reduction, 30% reduction of greenhouse gas emissions, and a 20% increase in construction research, together with downsizing the residential electricity consumption to 85 kWh/m2 with a national total of 6.4 TWh, and estimating zero energy buildings by 2050 (MINVU, 2015). Moreover, an annual growth of 2.6% in the productivity of the construction industry is expected. Therefore, national guidelines have been proposed to reduce the consumption of materials and waste generation, cost-effective prefab solutions for social housing, efficient use of water, sustainable thermal insulation, inventory management, control of residues, budget management and the introduction of renewable energies (CORFO and PMG, 2016).

Different standardization actions for construction procedures and conditions were initiated in the eighties, and regulations concerning residential thermal control and sustainable building studies were developed in the nineties, motivated by the increasing cost and deficiencies of national energy resources (CDT, 2010). Specifically, requirements of 1.6 to 1.9 W/m2k were established for thermal transmittance of walls in the most populated areas of the country, which implied adding interior or exterior thermal insulation to reinforced concrete partition walls and masonry. Later on, certifications and renewable energy programs have been applied, which have been pioneering in Latin America. Recently, prefabrication initiatives for housing, educational institutions and hospitals have been promoted, thus encouraging the use of BIM platforms for coordinating public construction professionals, and the introduction of digital management in the municipalities. Moreover, agreements between universities and private companies have been fostered in order to promote the installation of new technological centers, thus encouraging the introduction of 3D printed construction, among other experimental capabilities (CORFO, 2014).

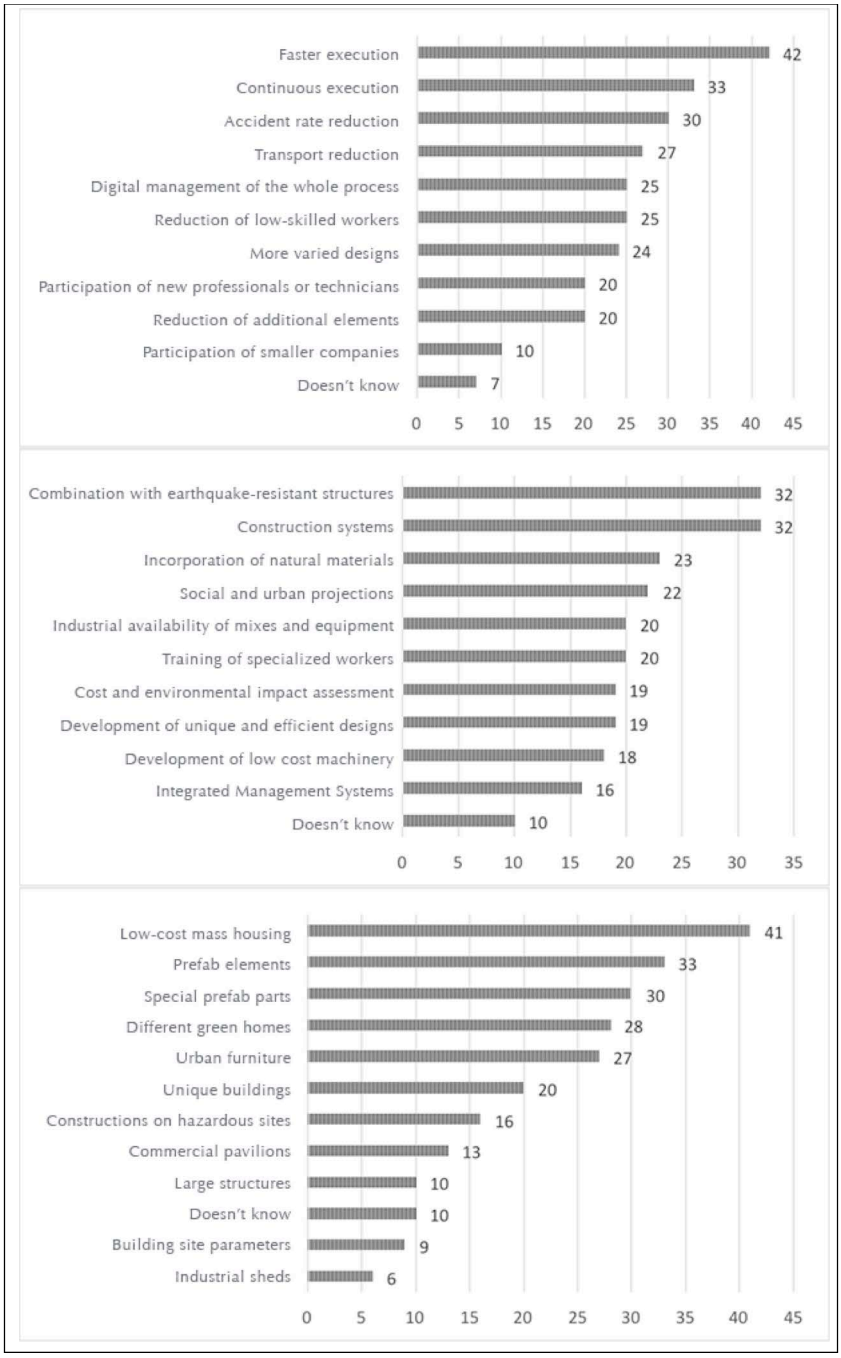

Figure 6. *Graphs of the answers to the questionnaire applied in the events addressing 3D printed construction (top: expected benefits; center: challenges; below: applications). Source: Self-prepared*

4.4 Dissemination

The presentations and communications about 3D printed construction carried out in the country in the last six months have had a great impact. All the proposed activities and notes were accepted and, in some cases, requested by the organizers, when generally only part of the activities or communications about technological developments in the industry are accepted. An adequate attendance and the recognition from the participants or

readers has been observed, demonstrated by direct observations during the conferences, which reveals a increasing interest on this technology from academics, professionals and general audience, but it is also the expression of similar concerns about the perspectives, where recurrent remarks were received regarding a possible replacement of the existing labor force and the seismic resistance of the buildings executed with this technology.

The registration site for the activity held in January 2009 was available a month ahead, and it was disseminated through digital media. The number of participants was restricted to 65 people, given the capacity of the room, and it was completed a week earlier, thus indicating a keen interest compared with other activities organized and disseminated in a similar way. Sixty four (64) surveys were completed before the opening of the activity, and the attendants declared that their main working area was construction (63%), followed by engineering (40%) and architecture (34%), considering that they could indicate more than one option (Figure 6). Furthermore, 60% came from private organizations, and the rest from public or academic institutions, more than half from outside the city. Most participants declared to be professionals (66%), followed by teachers and researchers (24%).

In relation to their previous knowledge of the technology, 53% expressed to have seen examples of 3D printed construction, and 17% declared they did not know about it; the rest indicated they had reviewed, participated in or analyzed experiences. Regarding the type of equipment, 31% declared they did not know any of them, 41% identified robots and 36% recognized the gantries with rails. Among the benefits, 71% valued the execution speed, 56% the continuity of the processes and 51% the accident rate reduction. In the question about the challenges of printed construction, a wide range of alternatives were indicated, highlighting the development of appropriate mixes (63%), the construction systems and earthquake-resistant structures (54%). As for the applications, the preferences were more concentrated, especially in low-cost mass housing (69%) and prefab elements (56%). The event showed an important level of attendance, thus demonstrating their interest and concerns regarding the technological possibilities and product development.

5. Discussion

As shown by different experiments described globally, the 3D printed construction is a new technology that allows building construction elements through processes suggesting substantial advantages compared with traditional construction methods. These experiences are mostly focused on the extrusion of material in vertically stacked layers, thus forming parts with different shapes, such as double-curved walls with an interior void, and sometimes completing a house or small building of one or two floors. Additionally, most of the reports aim solely at reviewing the mixes, commenting experiences or executing isolated elements, but they are not implemented in real buildings. According to the descriptions in the documents, the properties of extruded materials and the productive capacities of the equipment have been evaluated, but there is still not much information about the costs or procedures currently applied in the construction industry, which would allow verifying the suggested benefits. Therefore, this technology should be considered as an emerging one, with no mass dissemination to date, and with different technical, industrial and commercial challenges ahead.

Construction in Chile shows a dynamism and objectives characterized by the requirements to improve the productivity and the environment quality, where the government plays an important role in promoting technological advances by encouraging a joint development between companies and universities. This has raised expectations regarding the introduction of new technologies, such as 3D printed construction systems, although efforts should focus on specific initiatives and achievements. The need to reduce the energy consumption due to heat losses and infiltrations in the vertical envelope and the interests in increasing the productivity through digital management and prefabrication can be combined in industrialized wall systems with improved technical features. The constant demand for low cost housing shows the need for a special approach in the application of new technologies in small buildings, but the concerns expressed by investors and professionals regarding the consequent labor force reduction, and earthquake-resistant requirements for the structures in Chile, generates specific challenges in the country with regard to the introduction of innovating construction technologies.

6. Conclusions

This perspective of international documents and experiences concerning the 3D printed construction, together with the national expectations on the matter, reveals an emerging development and interest, with an increasing number of studies and tests in recent years around the world, and an expectant view from the industry. Nevertheless, it should be recognized that this technology is still incipient, it has not consolidated nor industrialized products, equipment or characteristics.

The studied publications explain different experiences and technical challenges, with a wide range of lines of development and not much connection between them, in addition to a diversity of potential benefits. This fact shows the emergence of a technology that must gradually lean towards more precise procedures, applications and advantages. The reviewed cases reveal the feasibility of the techniques used, their productive capacity and the public interest in this technology. However, the reported initiatives are very specific, which does not suggest a significant introduction of this technology in the construction sector. As for these possibilities in Chile, and the motivations of 3D printed construction professionals, there is a relevant correlation between their predicted capacities and the possibilities of increasing the productivity, reducing time and resources, together with the digitalization and control of the processes, or the possibilities to improve the sustainability of materials, construction activities and buildings, while reducing the energy consumption. Nevertheless, a substantial investment on research is required, given the current conditions of this technology. A special interest is observed in the production of housing areas with higher thermal performance, in addition to solving the earthquake-resistant aspects and their integration with local construction processes to define adequate construction systems for the Chilean context. The introduction of new technologies, such as 3D printed construction, must include the academic, commercial and state participation, together with different disciplines, such as robotics, structural engineering, architecture and construction, among others, focused on specific achievements for the buildings.

The present review of the new technology of 3D printed construction and its relationship with national challenges is also an example of the strategic analysis to guide the perspectives of the university education, the government and the industry, in the search for innovating advances to improve the role of the construction industry in the social development.

7. Acknowledgements

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