Chapter 14
Additive Manufacturing: Importance and Challenges for Latin America

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Abstract In this chapter, Rodríguez et al. (Res Educ 11(3):165–173, 2002) Competitive Technical Intelligence methodology is adapted and applied to an analysis of additive manufacturing technology. The global current stage of this technology and an assessment of its future potential are presented and compared with actual development in Latin America. Market information is also evaluated. Later, a scientometric patent and scientific literature analysis are used to compare global and regional circumstances in regard to this technology. The insights obtained from these assessments reveal that patent and research activity regarding additive manufacturing throughout Latin America is behind that of developed countries. However, some companies are making use of additive manufacturing in their current processes. A major adoption of this technology is expected to occur in Latin American as a result of the advancements in additive manufacturing.

Keywords Additive manufacturing · 3D printing · Additive fabrication · Latin America · Scientometrics · Patent analysis · Scientific analysis

14.1 Introduction

Additive manufacturing is the process of joining materials to make three-dimensional objects from digital models. Unlike traditional subtractive manufacturing methods, this process is usually developed layer upon layer (Scott et al. 2012). The term "3D printing" is more commonly used as a synonym for additive manufacturing (Wohlers Associates 2013). Consequently, both "additive manufacturing" and "3D printing" are used interchangeably in this chapter.

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The first patent related to this technology was granted on March 11, 1986 in the USA under the registration number 4,575,330. This patent, invented by (Hull 1986), was for the development of an "apparatus for production of three-dimensional objects by stereolithography." The latest of the former patents only recently expired (Basiliere 2014b).

The growth of this technology was slow during the first two decades; however, the 3D printing market has expanded dramatically since 2012. The participation of independent creators, hobbyists, and early adopters has begun to heavily publicize the subject (Basiliere 2014a). As an example of this great interest, 3D printing publications in specialized journals have grown from 1600 to 16,000 articles from 2011 to 2012, an increase of 10 times in a single year (Wohlers Associates 2013). Industries that are taking advantage of this technology include education, aerospace, defense, architecture, automotive, consumer products, electronics, and medical devices (Basiliere et al. 2014).

At present, the impact of additive manufacturing continues to grow in terms of commercial and scholarly activities (Bourell et al. 2009). Some commercially available products already use this technology; for example, a hip joint for general use manufactured by Arcam AB has been approved by the China Food and Drug Administration (Chen 2015). The US Food and Drug Administration (FDA) also certificated a robotic arm developed by DEKA Integrated Solutions Corporation to be manufactured, marketed, and made available to the US Veteran Affairs health system, though its release date has yet to be defined (U.S. Department of Veterans Affairs 2014). These advancements are expected to reduce surgery costs and improve patient quality of life. The importance of this technology is comparable to that of the development of the semiconductor, the computer, and the Internet (Wohlers Associates 2013).

This chapter presents a Competitive Technological Intelligence research on additive manufacturing technology. Market insights regarding this technology will be presented, and a scientometric patent and scientific literature analysis will be used to compare the state of the technology at both regional (Latin America) and global levels. The importance of this technology and the main challenges facing its development and adoption in Latin American countries will also be discussed.

This work is organized as follows: it starts with the definition of additive manufacturing and the different types that involves, after that the methodology that was developed to analyze this technology is presented, followed by a discussion of the results obtained concerning additive manufacturing market and the impact of the technology. The incursion of this technology in Latin America will then be discussed, and the scientific and patent productions at global and regional levels will be compared. The main challenges facing the implementation of this technology will be described, after which conclusions will be provided.

14.2 Additive Manufacturing Technology

The American Society for Testing and Materials (ASTM) defines additive manufacturing as the process of joining materials to make objects from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing methods (Mahamood et al. 2014). This process is also known as additive fabrication, additive processes, freeform fabrication, rapid prototyping, and 3D printing (Wohlers Associates 2013). The current study uses "3D printing" to refer to additive manufacturing, as this version of the term is most popular (Beer 2013; Shah and Basiliere 2014). Additive manufacturing can also be classified according to the technology used to create the final product. This will be discussed in the section below.

14.2.1 Types of Additive Manufacturing Technologies

This emerging technology is based on several methods that have been classified by the ASTM regarding seven different technologies, as shown in Table 14.1.

The use of these technologies depends on the desired product characteristics. Directed energy deposition technology, for example, is used during metal processing to produce high-quality metal parts for the military and aerospace industries. Powder bed fusion is well known for its production of complex geometries, which represents a big advantage for medical manufacturers in products like dental devices and knee implants (Basiliere and Shanler 2014).

Table 14.1 Additive manufacturing technologies

Technology	Definition
Binder jetting	Particles of powdered material are selectively joined using a liquid bonding agent
Directed energy deposition	Materials are fused via melting while they are being deposited; the fusion is achieved using a "focused thermal energy" such as a laser, electron beam, or plasma arc
Material extrusion	Material is dispensed through a nozzle or orifice in order to be selectively joined
Material jetting	Material in fine droplets is deposited to be selectively joined
Powder bed fusion	Particles of powdered material deposited in a bed are selectively fused using a thermal energy
Sheet lamination	Sheets of material are bonded to build an object
Stereolithography	Liquid photopolymer in a vat is selectively cured via light-activated polymerization

Adapted from: Basiliere (2015), Shah and Basiliere (2014)

14.3 Methodology

The Competitive Technology Intelligence methodology applied in the present study is based on a previous study by Rodríguez et al. (2002). A graphic description of each stage involved in the methodology is presented in Fig. 14.1.

14.3.1 Planning

The competitive technological intelligence process was developed in this stage to determine the requirements and set the main goals, objectives, and activities needed to carry out the current project. The research strategy was determined considering experts from academia and industry and relevant keywords found in databases and software search engines. Next, a scientific analysis of the existing literature on additive manufacturing and competitive technical intelligence was conducted. The purpose of this study was to refine and adapt the previous competitive technological intelligence methodology developed by the first author of the current research, as well as to compare the potential of additive manufacturing with its actual state in Latin America.

14.3.2 Information Evaluation

First, the primary and secondary sources of information at an international level were identified and evaluated. Experts[1] on additive manufacturing and competitive technical intelligence field were consulted, and databases related to the market, science, and technology were identified using meta-Internet searches. Additional sources of information, such as global reports from non-governmental organizations, were also included during the development of the project.

14.3.3 Information Collection

This stage consisted of gathering information from the previously identified secondary sources. The scope of this activity included analysis of global and regional market information regarding additive manufacturing, as well as of scientific and technological information at an international level. For market data, the latest information from specialized databases such as Gartner was consulted using previously determined keywords. Gartner is the world's leading information technology research and advisory

[1]From Tecnológico de Monterrey (Mexico) and Manchester University (UK).

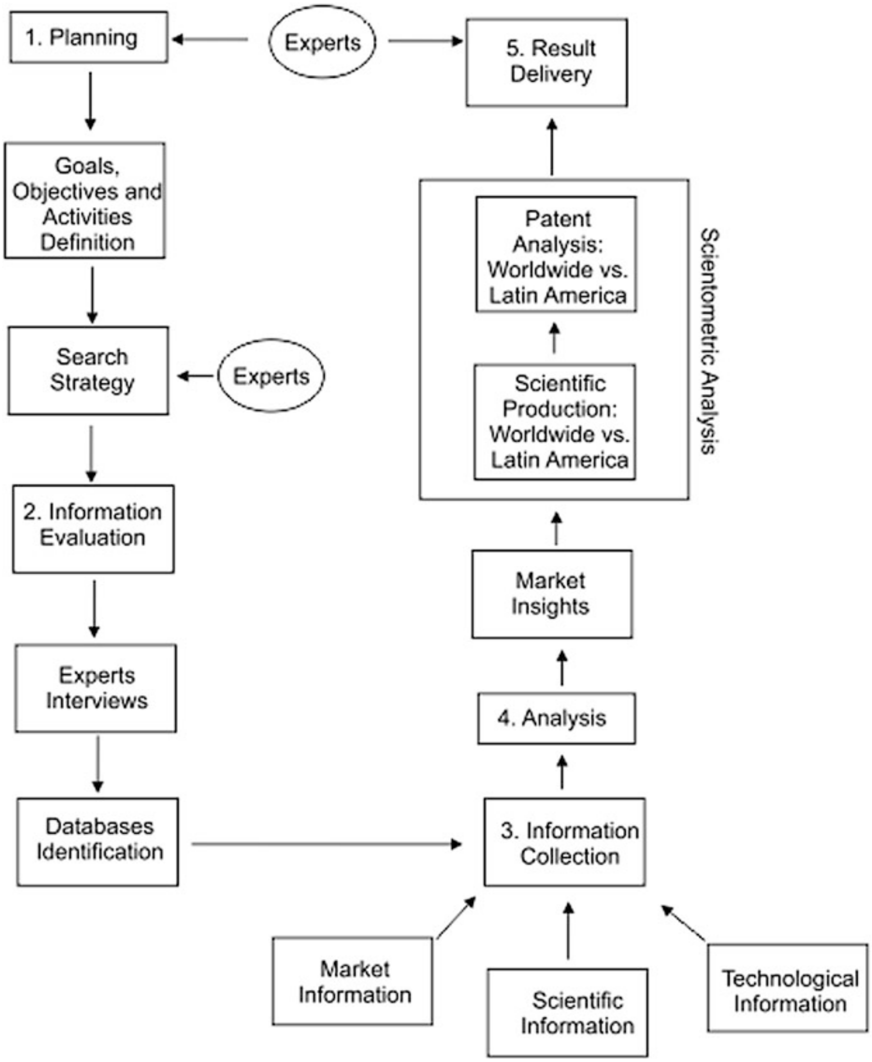


Fig. 14.1 Competitive technological intelligence methodology (Adapted from: Rodríguez et al. 2002)

company. It offers technology-related insight for strategic decision making (Gartner 2015). Next, roadmaps of advanced manufacturing were identified to support the determination of future development for additive manufacturing and definition of the challenges that the Latin American region could face.

The Scopus database was used to determine the dynamic and focus of the additive manufacturing scientific research in Latin America, covering from 1984 (when the first patent on additive manufacturing technology was applied for) to May 5, 2015 (when this stage of research ended). Scopus is the largest abstract and citation database of peer-reviewed literature. It brings an overview of the world's research output in the fields of science and technology, among other areas (Elsevier 2015). The Patent Insight Pro software was used to perform a network analysis of Latin American organizations developing additive manufacturing research. This software is a patent search and analytics platform that uses advanced text mining algorithms to analyze patents and scientific literature (Gridlogics 2015).

Regarding technological information, a scientometric patent analysis was developed by applying Patseer software. This is a global patent database and research platform with integrated analytic tools covering more than 92 million records from major authorities worldwide (Sinha and Pandurangi 2015). A time period from 1984 to June 17, 2015 was defined to perform the analysis. The search strategy for developing the current research is described below:

- Scientific information
  - TITLE-ABS-KEY ("Additive manufacturing" OR "Additive manufacture")
  - TITLE-ABS-KEY ("3D printing" OR "3D printer" OR "3D print")
  - TITLE-ABS-KEY ("Rapid prototyping" OR "Rapid prototype")
  - TITLE-ABS-KEY ("Additive fabrication")
  - TITLE-ABS-KEY ("Rapid manufacturing" OR "Rapid manufacture")
- Technological information
  - TAC: (Additive Manufacturing) OR (Additively Manufacturing) OR (Additive Manufacture)
  - TAC: (3D printing) OR (Three-dimensional Printing) OR (3D Printer)
  - TAC: (Rapid Prototyping) OR (Deposition Modeling)
  - TAC: (Additive Fabrication) OR (Rapid Manufacturing) OR (Dimensional Printer)

This stage included expert validation and a complementary review with additional information that was found during the study.

14.3.4 Analysis

All data were integrated before the gathered information was analyzed. Because different types of sources were involved, the information first had to be classified to standardize it and obtain a general perspective of the research. Irrelevant information and duplicates were removed. Market data were then analyzed to identify insights related to the research objectives. Scientific information was analyzed using the Scopus (classification by country) and Patent Insight Pro (correlation map) analytical tools. The patent analysis was performed with the aid of Patseer advanced software to determine the patent activity regarding additive manufacturing in Latin America and compare it with global statistics.

14.3.5 Results Delivery

This stage consisted of the dissemination of results via two methods. First, a comparison of the global standard for additive manufacturing against that currently in place in Latin America was presented to a Mexican research group that focuses on this technology. Second, the most important identified insights were presented in a specialized conference attended by researchers of additive manufacturing and technology mining.

14.4 Results

This section presents the results obtained from the research regarding the market and scientific and technological information about additive manufacturing. To begin, a general overview of the technology is provided below.

14.4.1 Prices in the Market

Insights obtained revealed that 3D printing is a relatively expensive technology as we can see in the following table. However, reductions in price are expected as use of the technology increases. The range of prices of the different additive manufacturing technologies available up to 2014 is presented in Table 14.2.

From Table 14.2, it can be observed that material extrusion is the most affordable technology, followed by stereolithography. Directed energy deposition and fusion bed of powder are the most expensive.

Table 14.2 Additive manufacturing price range

Technology	Price lower bound (USD $)	Price upper bound (USD $)
Material extrusion	500	400,000
Stereolithography	3000	800,000
Inkjet adhesive	5000	800,000
Inkjet material	20,000	600,000
Directed energy deposition	200,000	5,000,000
Fusion bed of powder	19,800	2,000,000
Lamination of sheets	37,000	1,000,000

Adapted from: Basiliere (2014a)

14.4.1.1 Cross-Industry Additive Manufacturing

Initially, additive manufacturing was only used for the development of prototypes (Mahamood et al. 2014). Currently, it is utilized in a wide range of industries, especially in areas such as consumer products and electronics (22 % of users of additive manufacturing technology worldwide), the automotive industry (19 %), medical and dental applications (16 %), industrial and business machines (13 %), and aerospace (10 %) (Wohlers Associates 2013). In addition, additive manufacturing is starting to be used to develop products of high added value such as human tissue, food, and airplane wings, and NASA recognizes 3D printing as an important technology for space exploration (Atlantic Council 2013).

Companies' motivators for using 3D printing devices are directly related to the new generation or improvement of products; however, companies also consider other factors like supply chains efficiency (Basiliere 2014a). The adoption of additive manufacturing accelerates the process of product commercialization; it pushes production to the customer and allows products to be more innovative in terms of design, faster production, etc. (Rodríguez et al. 2014).

14.4.1.2 Impact of Additive Manufacturing Technology in Industry

3D printing enables the creation of products in a faster and, in some cases, more affordable way. It is even possible to manufacture complex geometries and minimize inventory as production is pushed to the point of consumption (Cearley et al. 2015). At present, the range of applications for additive manufacturing among companies is varied and still growing as the technology becomes more specialized (Plummer et al. 2014). In addition, the emergence of new types of businesses as a consequence of the advantages of the additive manufacturing's special capabilities is expected. There are already successful cases of companies that could not have arisen without the prior existence of additive manufacturing; for example, Align Technology uses this technology to manufacture plastic aligners to replace metal orthodontia brackets (Wohlers Associates 2013). Moreover, global manufacturers such as General Electric, Boeing, and Ford are already using 3D printing machines to produce critical parts for airplanes, automobiles, and wind turbines (Atlantic Council 2013).

Additive manufacturing allows the reinvention of many old products and is expected to lead to the development of innovative new ones. In the future, there will not be limitations in design as additive manufacturing will enable people to print anything that can be modeled by a computer. In fact, it is expected that this innovative technology will create new industries and professions (Campbell et al. 2011). Despite this being an increasingly global technology, its use has yet been limited in developing countries such as those in Latin America, as will be discussed below.

14.4.1.3 Additive Manufacturing Incursion in Latin America

3D printing can be of great use, particularly for regions that lack significant production capacity and must depend on imports even for basic consumer goods. The cost of establishing a complete 3D printing facility is approximately USD $10,000, a much more feasible amount than what is required to set up a conventional factory (Atlantic Council 2013). In Latin America, interest in additive manufacturing technology is increasing. However, its adoption is in an emerging phase. A recent report grouped Latin American countries in the "other countries" section of an account of the additive manufacturing systems installed from 1988 through to the end of 2012; this entire "other" section represented only 12 % of the global total (Wohlers Associates 2013). The following are some examples of Latin American companies that installed additive manufacturing systems during this time frame:

- Thinker Thing Company, based in Santiago, Chile, developed an innovative process that allows consumers to design real-world objects using their own preferences. After the design stage, clients simply press the "print" button and their object, made of the material of their choice, arrives in the post. However, the company does not utilize its own 3D printers; it uses the 3D printing services of a US-based company (Thinker Thing 2015).
- Brazil is gaining experience with 3D printing mainly in the automotive sector. Although important multinational additive manufacturing companies have entered the Brazilian market, there are two local companies that manufacture their own devices using 3D printing (Wohlers Associates 2013):
  - Metamaquina is a Brazilian company that develops and produces low-cost 3D printers and 3D printing materials for its national market. The company also has laboratories where clients can learn to model and prototype objects (Metamaquina 2015).
  - Cliever also develops and produces 3D printers and 3D printing materials. In addition, the company has developed a software for modeling objects, and it offers other related accessories (Cliever 2015).
- Kikai Labs is an Argentine company that develops 3D printers and offers printing services. It also sells 3D printing materials produced in association with a regional material manufacturer. This company has won national awards for its entrepreneurial efforts (Kikai Labs 2015).

Additive manufacturing is one of the technologies with the greatest potential for improving Latin American education. A major adoption of this technology in the education field is expected to take place in the next three years, mainly for the development of educational prototypes. For example, students of mechanical and electrical engineering from Universidad de Piura, Peru utilized an affordable 3D printer to build car prototypes with educational purposes (Johnson et al. 2013). Furthermore, the Advanced Manufacturing Group of the Tecnológico de Monterrey, Mexico is devoting important research efforts to additive manufacturing technology (Cantú 2015). They also offer 3D printing services to companies looking for customized prototypes.

Important actions have also been taken by the Latin American healthcare industry. As an example, Brazil has already used 3D printing to produce patient-specific cranial adaptive prostheses for skull injuries. Uruguay is involved in a partnership with the Department of Capital and Technology-Intensive Sectors of Brazil for innovation in this field (United Nations 2015). In both cases, important efforts to develop this technology are being carried out.

At present, Latin America does not have a significant presence in the additive manufacturing field. However, while the presence of this technology is still low compared to that in other regions, its influence has begun to permeate the development of a variety of start-ups.

14.4.2 Additive Manufacturing Scientific Production in Latin America

Scientific production related to additive manufacturing technology in Latin America is in its infancy. This is demonstrated by the small number of papers published by individuals or researchers assigned to Latin American organizations. The results of the analysis of these papers are presented in Table 14.3.

Table 14.3 Additive manufacturing scientific research developed by Latin American individuals or organizations (own elaboration based on Scopus analysis)

Keyword	Number of papers (global)	Number of papers (Latin America)	Latin America (%)	Number of papers (Brazil)	Number of papers (Mexico)	Number of papers (other Latin American countries)
Additive manufacturing OR additive manufacture	2885	50	1.7	41	6	3
3D printing OR 3D printer OR 3D print	3914	81	2.1	55	13	13
Rapid prototyping OR rapid prototype	16,584	376	2.3	267	40	69
Additive fabrication	367	3	0.8	2	1	0
Rapid manufacturing OR Rapid manufacture	1499	26	1.7	22	4	0
Total	25,249	536	2.1	387	64	85

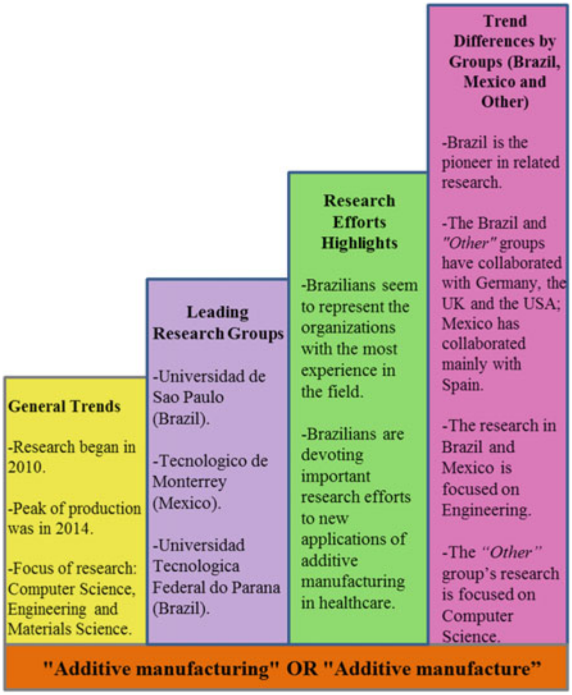


Fig. 14.2 Latin American scientific production of additive manufacturing based on "additive manufacturing" OR "additive manufacture" queries (own elaboration based on Scopus analysis)

This information demonstrates that only 2 % of the global scientific production related to additive manufacturing occurs in Latin American organizations, of which rapid prototyping is the field with the highest number of publications. As shown, 536 additive manufacturing papers were identified within the Latin American region; deeper analyses of these results are presented in Figs. 14.2, 14.3, 14.4, 14.5, and 14.6. These data were analyzed using the advanced tools of the Scopus database. Each figure presents the general trends, key research collaborations (country level), main research efforts, and differences by group (Brazil, Mexico, and Other) for each search strategy.

An analysis of the collaborations with Latin American organizations was made with consideration of the results of Table 14.3 (Brazil, Mexico, and Other). The following results were obtained (Table 14.4).

Now we drive our attention on the collaboration dynamics regarding the highest number of publications developed by Latin American organizations. In this respect, Fig. 14.7 illustrates a collaboration network that was established using the "rapid prototyping" results from the previous section (376 papers in total). The Renato Archer Center in Brazil conducts joint research with organizations such as the Imaging Department of Sao Paulo State University (Brazil) and Pontific Catholic University of Rio Grande do Sul (Brazil), as shown in the yellow circle in Fig. 14.7.

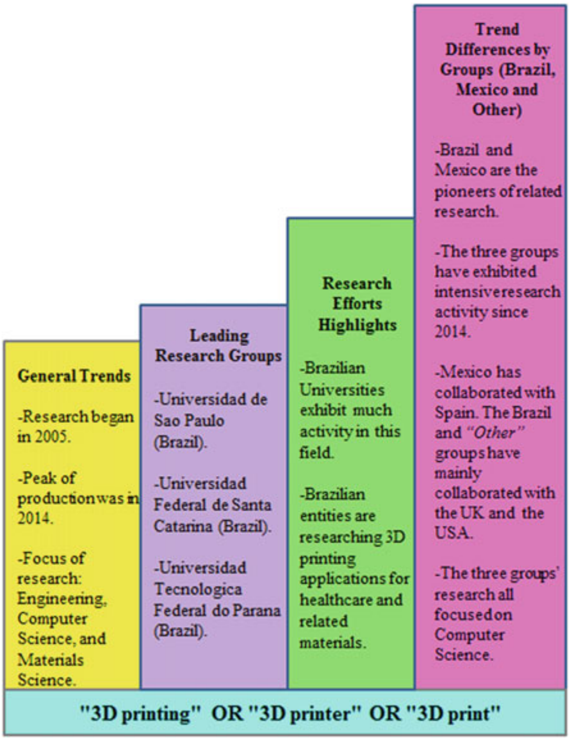


Fig. 14.3 Latin American scientific production of additive manufacturing based on "3D printing" OR "3D printer" OR "3D print" queries (own elaboration based on Scopus analysis)

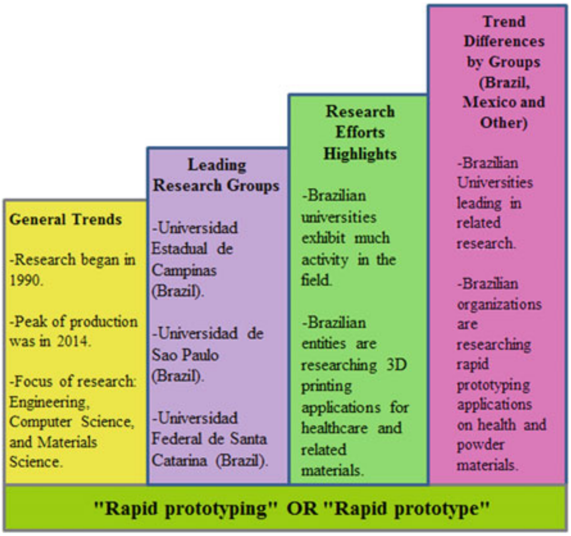


Fig. 14.4 Latin American scientific production of additive manufacturing based on "rapid prototyping" OR "rapid prototype" queries (own elaboration based on Scopus analysis)

Fig. 14.5 Latin American scientific production of additive manufacturing based on "additive fabrication" query (own elaboration based on Scopus analysis)

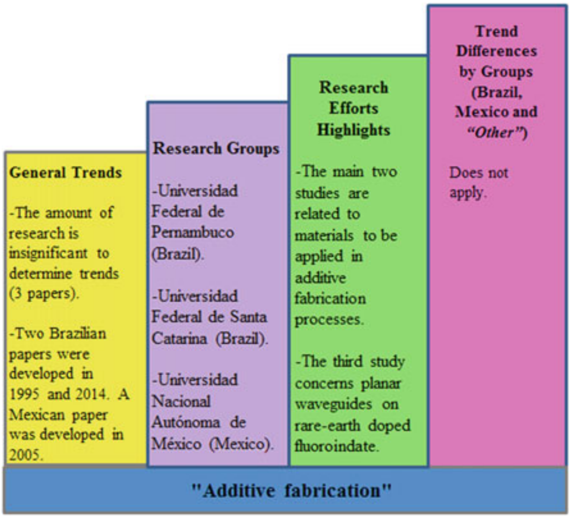
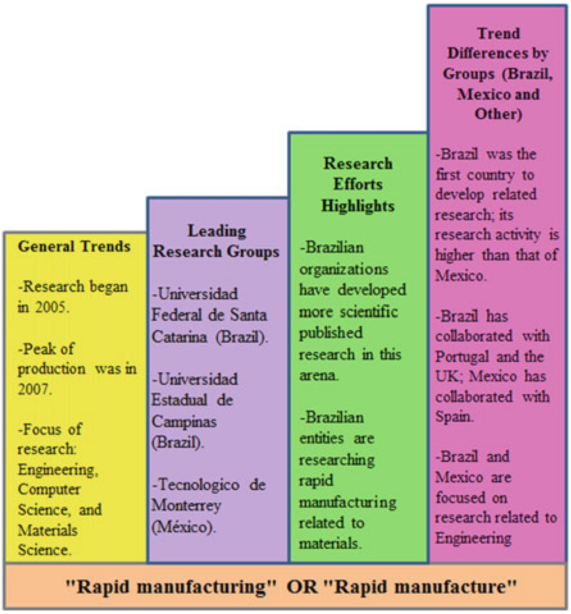


Fig. 14.6 Latin American scientific production of additive manufacturing based on "rapid manufacturing" OR "rapid manufacture" queries (own elaboration based on Scopus analysis)



Shown in the purple circles are Tsinghua University (China)'s research network that includes various Latin American organizations, such as Universidad Federal de Santa Catarina (Brazil), Universidad de Brasilia (Brazil), Instituto Médico ENERI (Argentina), and the Department of Surgery at Pontificia Universidad Católica Do Río Grande (Brazil). The green circle indicates a dense collaboration between organizations that include the University of Campinas (Brazil), Brazilian Telecom

Table 14.4 Examples of global organizations collaborating with each Latin American group (Brazil, Mexico, and Other) (own elaboration based on Patent Insight Pro analysis)

Keyword	Brazil		Mexico		Other Latin American countries	
	Brazilian organization	Collaborator	Mexican organization	Collaborator	"Other" organization	Collaborator
"Additive manufacturing" OR "additive manufacture"	Federal Institute of Santa Catarina	Aachen University, Laser Technology (Germany)	Tecnológico de Monterrey	Universitat de Girona (Spain)	University of Antioquia-GIB-Eafit (Colombia)	University of Buffalo (US)
	Escola de Matemática Aplicada FGV/EMAp	University of Brighton (UK)			Universidad Autonoma de Occidente (Colombia)	Rochester Institute of Technology (US)
	Federal University of Rio de Janeiro-UFRJ/COPPE	New York University (US)				
"3D printing" OR "3D printer" OR "3D print"	Federal University of Santa Catarina	Hewlett Packard Laboratories (US)	Lab. de Tecnologias de Información, CINVESTAV	Universite de Poitiers (France)	Instituto Tecnológico de Buenos Aires (Argentina)	Massachusetts Institute of Technology (US)
	Universidad Federal de Bahía (Brazil) and Escola de Matemática Aplicada	University of Brighton (UK)	Tecnológico de Monterrey	Universitat de Girona (Spain)	Universidad de Antioquia (Colombia)	University College London (UK)
"Rapid prototyping" OR "Rapid prototype"	Universidade Federal Do Rio De Janeiro	University of Maryland (US)	Universidad de las Americas	Texas A and M University (US) and Sandia National Laboratories (US)	Pontifi cia Universidad Catolica de Chile (Chile)	University of Texas at Austin (US)
	São Paulo State University	Instituto Politécnico de Leiria (Portugal)	Metalsa SA	University of Girona (Spain)	Central University of Venezuela (Venezuela)	Polytechnic University of Catalonia (Spain)

(continued)

Table 14.4 (continued)

Keyword	Brazil		Mexico		Other Latin American countries	
	Brazilian organization	Collaborator	Mexican organization	Collaborator	"Other" organization	Collaborator
"Additive fabrication"	Universidad Federal de Pernambuco	Without collaboration	Universidad Nacional Autonoma de Mexico	University of California at San Diego (US) and Osram Sylvania Central Research (US)	Does not apply	Does not apply
	Universidade Federal de Santa Catarina and Instituto Federal de Santa Catarina	Without International collaboration				
"Rapid manufacturing" OR "Rapid manufacture"	Universidade Federal de Uberlândia	Instituto Superior Tecnico, ICEMS (Portugal)	Tecnológico de Monterrey	University of Girona (Spain)	Does not apply	Does not apply
	Universidade Federal de Santa Catarina	Loughborough University (UK)				

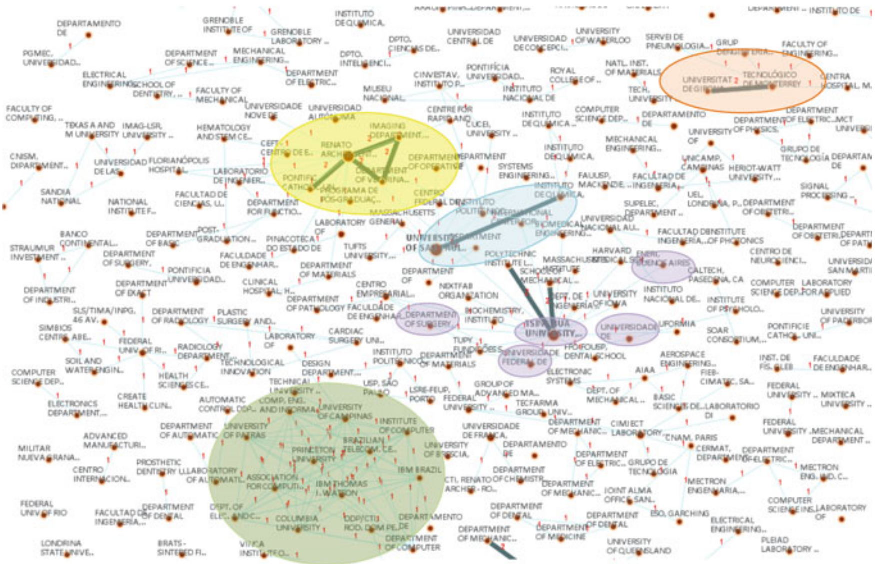


Fig. 14.7 Key research network on the Latin American scientific production of additive manufacturing. *Circles* indicate research networks, and lines show the number of joint papers (own elaboration based on Patent Insight Pro analysis)

(Brazil), IBM Brazil (Brazil), Columbia University (USA), IBM Thomas Watson Research Center (USA), and the University of Crete (Greece). The orange circle indicates the relationship between Tecnologico de Monterrey (México) and Universidad de Girona (Spain). Finally, the partnership between the University of Sao Paulo (Brazil) and the Instituto de Química of Universidad de Campinias (Brazil) is presented in the light blue circle.

Using previous analyses, research trends regarding additive manufacturing were determined as follows:

- Research on additive manufacturing and its related terms began in Latin America in 1990. Production has spiked in recent years, particularly since 2014.
- Research is focused mainly in the engineering field, followed by the computer (process optimization) and material sciences.
- Brazil has pioneered developing additive manufacturing research since 1990, exhibiting intensive activity.
- Some collaboration efforts have developed between Latin America and countries including Spain, the UK, and the USA. However, their joint research production is low compared to that by Latin American organizations alone.
- Most research leaders are from Brazilian universities, such as Universidad de Sao Paulo, Universidad Estadual de Campinas, and Universidad Federal de Santa Catarina.

- Brazil has conducted intensive research of the technology compared to work conducted in other Latin American countries. The strong national collaboration among Brazilian organizations could be the result of the key research network analysis that has been developed. The main innovative research focus of the collaborating organizations is on healthcare applications (e.g., bio-printing, scaffolds, dental devices, and implants).

14.4.3 Additive Manufacturing Patent Production in Latin America

Although there is growing interest in additive manufacturing in Latin America, the rate of related patent production is not significant. This appreciation remains in the low percentage (0.02 %) of additive manufacturing inventions developed and patented by Latin American organizations or individuals compared to worldwide production rates. These figures are shown in Table 14.5.

Of the three obtained patents detailed in Table 14.5, the Mexican invention involves the use of 3D printing to manufacture centrifuge support; the Brazilian patent focuses on using 3D printing to develop bone scaffolds (patented by two different authorities, Brazil and WIPO); and the Chilean patent involves the development of a 3D printing support for 2D printing. This last invention has been patented by 14 different patent authorities in Mexico, Russia, Argentina, Canada, Europe, Japan, and others.

14.4.4 Additive Manufacturing and Challenges for Latin America

Countries around the world are placing additive manufacturing at the core of their strategies for development. Important investments are being made in the research and development of additive manufacturing technologies as part of the governmental strategies in the USA, Japan, China, Singapore, South Africa, Australia, Belgium, France, Germany, the Netherlands, Poland, Portugal, Spain, Sweden, the UK, and others (European Commission 2014). The European Factories of the Future Research Association (2013) developed a roadmap by which to determine the ongoing importance of manufacturing in the European economy and develop a vision for this sector up to the year 2030. To respond to world challenges, it is expected that factories will have to be green and sustainable, use small amounts of resources, consume little energy, and produce zero emissions and waste. In fact, the Association previously mentioned specifies the importance of using new manufacturing technologies, such as additive manufacturing, to develop sustainable business.

Table 14.5 Additive manufacturing patent production in Latin America (own elaboration based on Patseer analysis)

Keyword	Number of patents (global)	Number of patents (Latin America)	Latin America (%)	Number of patents (Brazil)	Number of patents (Mexico)	Number of patents (Chile)	Number of patents (other Latin American countries)
Additive Manufacturing OR additively manufacturing OR additive manufacture	1957	0	0.00	0	0	0	0
3D printing OR Three-dimensional Printing OR 3D Printer	5417	2	0.04	0	1	1	0
Rapid prototyping OR deposition modeling	4468	1	0.02	1	0	0	0
Additive fabrication OR rapid manufacturing OR dimensional printer	2022	0	0.00	0	0	0	0
Total	13,864	3	0.02	1	1	1	0

The aerospace, automotive, and electronic sectors are the most propitious European industries to develop additive manufacturing business in the future. By 2020, these industries are expected to be characterized by customization; this will foster the utilization of additive manufacturing technology, mainly to develop more innovative products. However, some requirements should be considered to ensure the correct adoption of additive manufacturing in producing such innovations; these include process stability, certifications, design rules, and the ability to control part quality during the production process (Gausemeier 2013).

Experts in the additive manufacturing field predict a promising future for this technology. In the next 10–15 years, it is expected that this technology will become an integral component of available manufacturing processes, especially for metallic parts; machines producing 3D mechanical and electrical components are expected to become commonplace. Moreover, the mass production of low-cost 3D printers is anticipated to meet the projected home and office demands of consumers. Bio-printing also represents a highly promising application of additive manufacturing. Functional tissue and organs may be able to be fabricated using these methods within the next 10–15 years. Designers will not have limitations; they will be able to meet every product requirement in terms of design and materials. It is expected that there will be large factories, regional assembly centers, and local 3D printing shops to support the growing industry. To help these predictions come true, governments should create research programs that support such developments. Experts have determined that in addition to focusing research efforts on new additive manufacturing materials and processes, it will be necessary to investigate design and implementation aspects (Bourell et al. 2009).

As the global acceptance of additive manufacturing technology becomes a reality, Latin America will have to adopt the technology as well. However, some challenges must be addressed for this region to enter this worldwide dynamic. At this moment, additive manufacturing is characterized by low volume production and high prices. The cost of machines, materials, and maintenance inhibits the wider adoption of the technology (Bourell et al. 2009). In this regard, Latin America is at more of a disadvantage than other regions, partly because Latin American countries are characterized by low purchasing power. In 2014, the Latin American Gross Domestic Product (GDP) per capita based on purchasing power parity (PPP) was 12,443 USD (Comisión Económica para América Latina y el Caribe 2014). This is low compared to countries such as the USA, France, and Japan, which have GDP per capita based on PPPs of 53,000, 37,500, and 36,000 USD, respectively (The World Bank 2013).

For Latin America to develop sustainably, investment in the production and export of advanced technologies is necessary (Atilano et al. 2015); this includes additive manufacturing. With the exception of Brazil, Chile, and Mexico, Latin American economies exhibit low technological development due to several factors, including the restricted access to knowledge with high added value, low productivity, consumerism (high imports of technological goods and services), unqualified human resources, low public and private investment in research and development activities, and a lack of policies to improve the environment for dissemination and technological innovation. Patent production is relatively low and focuses on the traditional sectors of manufacturing, chemicals, petroleum, and steel. This could be the result of a lack of national policies for the management of intellectual property systems (Serrano 2014).

In the more advanced countries of Latin America, such as Mexico, there is an awareness of the importance of developing advanced manufacturing technologies to achieve sustainable economic growth. The Mexican government has already developed advanced manufacturing roadmaps that focus on talent management and on boosting the capabilities of the design, development, and engineering of processes, products, and materials produced in Mexico (ProMéxico 2011). It is hoped that most other Latin American countries will follow the example of the more advanced ones; however, such progress takes time. In the meantime, there is a need for strategy if these countries are to face the outlined challenges successfully.

The results of this research offer valuable information about the state of additive manufacturing in Latin America. There is a growing interest in this technology in the region. Global additive manufacturing developers might find the insights achieved in this study useful; they might, for example, use this study's results to identify the leading organizations researching additive manufacturing technology, their research focus, key research networks, organizations that are already commercializing these processes, and related patent inventions. Such information, as well as information regarding what potential competitors are already doing, could be useful to developers who wish to devise strategies by which to introduce and implement this technology in Latin America. In summary, the results of this research are of great strategic value in the additive manufacturing industry.

14.5 Conclusions

Additive manufacturing or 3D printing is an innovative technology that is changing conventional production processes and gaining ground in worldwide markets. The most valuable characteristic of this technology is its capacity to produce high-quality objects with complex geometries. Because of these advantages, successful and innovative business has been developed around additive manufacturing.

There are high expectations for the acceptance of this technology, not only in developed countries but also in developing ones. However, Latin America seems to be accepting the technology at a slower pace, as demonstrated by the low amount of scientific literature and patent production related to additive manufacturing in these countries. Results obtained from the present study's scientific literature production analysis indicate that while 25,249 papers related to additive manufacturing were developed worldwide between 1984 and 2015 (through May 5), only 536 were produced by individuals or researchers assigned to Latin American organizations (i.e., 2 %, the majority of which were from Brazil and Mexico). Further, the results of the patent analysis conducted in this review reveal no significant patent production related to additive manufacturing currently occurring in Latin America. Of the worldwide data regarding patent production related to this technology (13,864 records) from 1984 to 2015 (through June 17), only 0.02 % correspond to Latin America.

There is an observable global trend toward the development and adoption of technologies that make manufacturing processes more sustainable. Advanced countries, such as the USA, Japan, and France, have assigned great importance to this subject by developing long-term technology strategies that will enable them to maintain and increase their competitiveness. Results of this research show that Latin America is far behind that which is happening globally. There is an emerging interest in researching and developing new technologies like additive manufacturing; however, no strategic plans in the form of roadmaps have been identified for this technology in the Latin American region. Latin American countries face significant challenges regarding the adoption of advanced technologies such as additive manufacturing; such obstacles include the scant access to high-value knowledge and inadequate governmental policies to stimulate strong technological innovation. However, countries such as Brazil and Mexico demonstrate the greatest progress in the additive manufacturing adoption process; thus, it may still be that other countries of the region will follow their example.

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References

Atilano, A., Mercado, J., & Casanova, H. (2015). Indicadores de innovación tecnológica de los países de américa latina y el caribe. Banco de Desarrollo de América Latina. http://scioteca.caf.com/handle/123456789/724. Accessed 11 June 2015.

Atlantic Council. (2013). Envisioning 2030: US strategy for the coming technology revolution. The Atlantic Council of the United States. http://www.atlanticcouncil.org/images/publications/Envisioning_2030_US_Strategy_for_the_Coming_Tech_Revolution_web.pdf. Accessed 01 Apr 2015.

Basiliere, P. (2014a). Market guide for 3D printing. Gartner. http://www.gartner.com/document/2934020?ref=QuickSearch. Accessed 25 Mar 2015.

Basiliere, P. (2014b). Technology overview for stereolithography 3D printing. Gartner. http://www.gartner.com/document/2755618?ref=QuickSearch. Accessed 25 Mar 2015.

Basiliere, P. (2015). Technology overview for binder jet 3D printing. http://www.gartner.com/document/2981218?ref=QuickSearch. Accessed 25 Mar 2015.

Basiliere, P., Halpern, M., Burt, M., & Shanler, M. (2014). Cool vendors in 3D printing. Gartner. http://www.gartner.com/document/2726917?ref=QuickSearch. Accessed 25 Mar 2015.

Basiliere, P., & Shanler, M. (2014). Hype cycle for 3D printing. Gartner. http://www.gartner.com/document/2803426?ref=QuickSearch. Accessed 25 Mar 2015.

Beer, N. (2013). Additive manufacturing. Turning mind into matter. Sierra College Center for Applied Competitive Technologies (CACT). http://sierracollegetraining.com/uploads/201307/sierra-college-cact-additive-manufacturing-report-and-recommendations-may2013.pdf. Accessed 11 June 2015.

Bourell, D., Leu, M., & Rosen, D. (2009). Roadmap for additive manufacturing identifying the future of freeform processing. The University of Texas at Austin, Laboratory for Freeform Fabrication Advanced Manufacturing Center, United States. https://wohlersassociates.com/roadmap2009.pdf. Accessed 11 June 2015.

Campbell, T., Williams, C., Ivanova, O., & Garrett, B. (2011). Could 3D printing change the world? Technologies, potential, and implications of additive manufacturing. Atlantic Council. http://3dprintingindustry.com/wp-content/uploads/2013/05/Atlantis-Report-on-3D-printing.pdf. Accessed 11 June 2015.

Cantú, F. (Ed.). (2015). Strategic research groups. Tecnológico de Monterrey. http://www.sitios.itesm.mx/webtools/research/ITESMResearchGroupsBrochure2015.pdf. Accessed 11 June 2015.

Cearley, D., Walker, M., & Blösch, M. (2015). The top 10 strategic technology trends for 2015. Gartner. http://www.gartner.com/document/2964518?ref=QuickSearch. Accessed 25 Mar 2015.

Chen, S. (2015). This is just the beginning: China approves world's first 3D-printed hip joint for general use. Science and Research. http://www.scmp.com/tech/science-research/article/1854369/just-beginning-china-approves-worlds-first-3d-printed-hip. Accessed 08 Dec 2015.

Cliever. (2015). Productos. http://www.cliever.com.br/. Accessed 08 June 2015.

Comisión Económica para América Latina y el Caribe. (2014). CEPAL publica estimaciones de las paridades de poder adquisitivo de los países de la región. http://www.cepal.org/es/noticias/cepal-publica-estimaciones-de-las-paridades-de-poder-adquisitivo-de-los-paises-de-la-region. Accessed 09 June 2015.

Elsevier. (2015). Scopus. http://www.elsevier.com/solutions/scopus. Accessed 08 June 2015.

European Comission. (2014). Additive manufacturing in FP7 and horizon 2020. Report from the EC workshop on additive manufacturing held on 18 June 2014. http://www.rm-platform.com/linkdoc/EC%20AM%20Workshop%20Report%202014.pdf. Accessed 11 June 2015.

European Factories of the Future Research Association. (2013). Factories of the future. Multi-annual roadmap for the contractual PPP under horizon 2020. http://www.effra.eu/. Accessed 11 June 2015.

Gartner. (2015). About Gartner. http://www.gartner.com/technology/about.jsp. Accessed 08 June 2015.

Gausemeier, J. (2013). Thinking ahead the future of additive manufacturing. Innovation roadmapping of required advancements. Direct Manufacturing Research Center, University of Paderborn., Germany. http://dmrc.uni-paderborn.de/fileadmin/dmrc/Download/data/DMRC_Studien/DMRC_Study_Part_3.pdf. Accessed 11 June 2015.

Gridlogics. (2015). Patent insight pro. http://gridlogics.com/?portfolio=patent-insight-pro-by-gridlogics. Accessed 07 Oct 2015.

Hull, C. (1986). Apparatus for production of three-dimensional objects by stereolithography. US patent 4575330.

Johnson, L., Adams Becker, S., Gago, D. Garcia, E., & Martín, S. (2013). NMC perspectivas tecnológicas: educación superior en américa latina 2013–2018. Un análisis regional del informe horizon del NMC. Austin, Texas: The New Media Consortium. http://www.oei.es/noticias/spip.php?article13253. Accessed 11 June 2015.

Kikai Labs. (2015). Servicios. http://kikailabs.com.ar/servicios/. Accessed 08 June 2015.

Mahamood, R., Akinlabi, E., Shukla, M., & Pityana, S. (2014). Revolutionary additive manufacturing: An overview. *Lasers in Engineering (Old City Publishing), 27*, 161–178.

Metamaquina. (2015). Metamaquina. http://metamaquina.com.br/. Accessed 09 June 2015.

Plummer, D., Fiering, L., Dulaney, K., McGuire, M., Da Rold, C., Sarner, A., et al. (2014). Top 10 strategic predictions for 2015 and beyond: Digital business is driving 'big change'. Gartner. http://www.gartner.com/document/2864817?ref=lib. Accessed 25 Feb 2015.

ProMéxico. (2011). Diseñado en México. Mapa de ruta de diseño, ingeniería y manufactura avanzada, ProMéxico: México DF. http://www.promexico.gob.mx/documentos/mapas-de-ruta/MRT-Manufactura-Avanzada.pdf. Accessed 11 June 2015.

Rodríguez, M., Cruz, P., Avila, A., Olivares, E., & Arellano, B. (2014). Strategic foresight: determining patent trends in additive manufacturing. *Journal of Intelligence Studies in Business*, *4*(3).

Rodríguez, M., Eddy, A., & Garza, R. (2002). Industry/university cooperative research in competitive technical intelligence: a case of identifying technological trends for a Mexican steel manufacturer. *Research Evaluation, 11*(3), 165–173.

Scott, J., Gupta, N., Weber, C., Newsome, S., Wohlers, T., & Caffrey, T. (2012). Additive manufacturing: Status and opportunities. *Science and Technology Police Institute*.

Serrano, E. (2014). Desarrollo tecnológico y Brecha tecnológica entre países de América Latina. *Ánfora, 21*(36), 41–65.

Shah, Z., & Basiliere, P. (2014). Technology overview for powder bed fusion. Gartner. http://www.gartner.com/document/2830619?ref=QuickSearch. Accessed 25 Mar 2015.

Sinha, M., & Pandurangi, A. (2015). Guide to practical patent searching and how to use PatSeer for patent search and analysis. Gridlogics Technologies Pvt. Ltd. http://patseer.com/2015/04/e-book-patent-searching/. Accessed 29 Apr 2015.

The World Bank. (2013). GDP per capita, PPP (current international $). http://data.worldbank.org/indicator/NY.GDP.PCAP.PP.CD. Accessed 09 June 2015.

Thinker Thing. (2015). About. http://thinkerthing.com/about/. Accessed 08 June 2015.

United Nations. (2015). Exploring advanced technologies in Latin America. http://www.unido.org/news/press/exploring-advanced-t.html. Accessed 09 June 2015.

U.S. Department of Veterans Affairs. (2014). DEKA advanced prosthetic arm gains FDA approval. Office of research and development. http://www.research.va.gov/currents/spring2014/spring2014-34.cfm. Accessed 08 Dec 2015.

Wohlers Associates. (2013). Wohlers report 2013, additive manufacturing and 3D printing state of the industry, annual worldwide progress report. Fort Collins, Colorado, USA: Wohlers Associates, Inc. https://wohlersassociates.com/2013report.htm. Accessed 11 June 2015.