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# Review, Analysis, and Classification of 3D Printing Literature: Types of Research and Technology Benefits

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***Abstract***— *This paper presents a review, analysis and classification about 3D printing. Through the CAPES Sucupira platform, 124 articles with a high degree of relevance published between the years 2014 and 2018 were selected. Each of these articles was classified by means of 9 categories: study types, affiliation, approach, origin of the study, geographic scope, unit of analysis, scope, benefits and negative points. Through the results obtained, it was verified that the number of articles on 3D printing is increasing every year, which indicates its importance and popularity. Most of the time, scientific research is conducted and led by people connected to universities in Europe, Asia and the Americas. And finally, the number of citations related to the benefits of 3D printing are greater than the number of citations on the negative points of the process.*
***Keywords***— ***3D printing, additive manufacturing, literature review.***

## I. INTRODUCTION

The competition between companies of any industrial sector grows more and more each year. In this way, companies seek to reduce costs and deadlines and, at the same time, are pressured to develop and deliver products of high quality and performance. This competition generates the need to launch a new product in the market with a greater frequency and, consequently, the demand for new projects and development of new products grows. It is at this stage that 3D printing stands out (LOPES, 2016).

Popularly known as 3D printing, this process has many other names such as rapid prototyping (RP), additive manufacturing (AM) additive techniques, additive processes, among others (LOPES, 2016).

Within a few minutes or hours, this manufacturing process allows to produce complete products from a CADsoftware, using the most diverse raw materials and without a great human intervention. 3D printing has as its characteristic to construct three-dimensional pieces by means of the addition of successive thin layers, one on top of the other, until the formation of the desired product (ABREU, 2015; LOPES, 2016).

As mentioned earlier, additive manufacturing is an important technology in the development phase of the product. Its benefits are (LOPES, 2016): less time in the product development phase, lower costs, possibility of performing several tests and prototypes, increase product complexity without increasing deadline, decrease in project delivery time.

### 1.1 Historic

The first known 3D printer was invented and patented by Charles W. Hull in 1986. In his patent he describes a method where it is possible to fabricate objects by solidifying layers of a photo polymer (resin). This process was called stereolithography (ABREU, 2015, AGUIAR, 2014).

Three years later, in 1989, Scott Crump patented another 3D printing equipment that uses a different method than the Charles Hull printer, called Fused Deposition Modelling (FDM). Through the ability to move along three axes, the nozzle of the printer deposits a molten material, and layer by layer the final object is produced. (AGUIAR, 2014).

However, the rapid prototyping process became better known and accessible in the early 2000s. With the expiration of FDM patents, Adrian Bowyer created the RepRap (Replicating Rapid Prototyper), where the software of the equipment is free, its source code is open and 57% of the mechanical 3D printer components are manufactured through the additive manufacturing process (concept of self-replicating machine). In this way, in 2004 the first low-cost 3D printer appeared (ABREU, 2015).

By having an open system, many people were interested in developing and enhancing Adrian Bowyer's original design, and thus, the 3D printer has become cheaper, more accessible and more efficient (ABREU, 2015).

### 1.2 Different Types of 3D Printing

Over the years, the evolution of technology has had a major impact on the development of other 3D printing processes. The following are the most applied processes.

#### *1.2.1 Stereolithography (SLA)*

As previously mentioned, stereolithography was the first 3D printing process created and, according to Abreu (2015), is the most used type of additive manufacture.

By means of the incidence of an ultraviolet laser, a layer of liquid resin is solidified. After this step, the platform where the solidified resin layer is located is moved slightly downward, causing a layer of liquid resin to be added. Again, the laser solidifies the resin creating a second layer. This process is repeated until the object is completely constructed (ABREU, 2015; LOPES, 2016; BIKAS et al., 2016).

#### *1.2.2 Fused Deposition Modelling (FDM)*

As explained earlier, the FDM process was the second type of additive manufacture created and is one of the most used processes because of its low cost.

In this process, thermoplastic filaments are heated in the extruder and deposited on the construction platform by means of the extrusion nozzle. The construction platform has a lower temperature than the deposited thermoplastic, causing it to solidify rapidly. The platform moves down, and the nozzle of the extruder deposits the second layer of material. This process is repeated until the object is created. (ABREU, 2015; LOPES, 2016; BIKAS et al., 2016).

#### *1.2.3 3DP*

Unlike the processes mentioned above, the 3DP uses as a raw material a ceramic powder and a liquid binding agent. In the first step, a layer of ceramic powder is evenly distributed on the building surface. Subsequently, the liquid binding agent is applied over the desired area by means of a jet. In the third step, a piston recedes, causing the object's construction surface to move downwards. Thereafter, a new layer of ceramic powder is added, followed by the liquid binder. This procedure is repeated until the piece reaches its final shape. The piece is removed from the machine and a jet of compressed air is applied in order to remove uncoated powder from the model. The prototypes manufactured using the 3DP method are fragile, and to make them more rigid it isnecessary to subject them to a process of infiltration of resins (ABREU, 2015; BIKAS et al., 2016).

#### *1.2.4 Selective Laser Sintering (SLS)*

Like the 3DP process, selective laser sintering also uses a powder (usually thermoplastic, nylon or metal) as the raw material. This material is arranged in a homogeneous layer and a laser is applied to melt its particles, and thus solidify the material. This procedure is performed many times until the part is ready (LOPES, 2016; BIKAS et al., 2016).

#### *1.2.5 Laminated Object Manufacturing (LOM)*

This process can use different types of raw material, such as paper, plastic or metal. The material is laminated by a heated roller and glued to the bottom layer. Thereafter, it is cut by means of a laser (LOPES, 2016; BIKAS et al., 2016).

### 1.3 Steps of 3D Printing

To develop a project via 3D printing, you need to perform the following steps (AZEVEDO, 2013; OLIVEIRA, 2016):

- Develop a project of the desired object in 3D CAD software, such as SolidWorks, Inventor, AutoCAD, among others;
- Convert the project to STL (Standard Tecelation Language) format. This format describes surfaces of an object through a set of triangles of different dimensions. The more triangles there are, the greater the project accuracy;
- The next step is to choose a reference plane from the STL file, and so the object will be divided into layers parallel to the chosen reference plane. The smaller the size of the layer, the more accurate the print will be;
- Each of these layers is described by a file called GCODE. This code has the numerical commands for the manufacture of each of the layers, possessing information of temperature, trajectory, speed, positioning, among others;
- Finally, printing is done using the GCODE code, which directs the printer to obtain the desired object.

### 1.4 Application

Today, rapid prototyping has a very broad reach. It can be used in the most different industries, institutions of education from the fundamental level up to the higher level and for private use (individuals).

#### *1.4.1 Aerospace Industry*

It was one of the first areas to use the benefits of 3D printing to create prototypes quickly. The components of the aviation industry have a complex geometry and use advanced materials (advanced metal alloys such as:

titanium, nickel superalloys and special steels), which makes additive manufacturing a viable option (LOPES, 2016; BAHNINI et al.,2018).

*1.4.2 Car Industry*

The automotive industry was also one of the first to use 3D printing for the rapid development of prototypes / products and then began using the technology to manufacture the parts used in cars. Braking systems, drive shafts and gearbox parts are some examples of parts that are manufactured through additive manufacture (LOPES, 2016; BAHNINI et al.,2018).

*1.4.3 Medicine and Dentistry*

Like the two sectors mentioned above, the health area was also one of the first to use the technology. 3D printing is a great way to manufacture prostheses and implants, as these products require a high degree of customization due to the different morphological characteristics of each patient (LOPES, 2016; BAHNINI et al.,2018).

The next step in 3D printing that will revolutionize the medical world is 3D bioprinting, where the goal is to create bones, tissues and living organs (LOPES, 2016; BAHNINI et al.,2018).

*1.4.4 Art and Fashion*

Artistic class and fashion also surrendered to the benefits of 3D printing. Plastic artists have found an easier and more direct way of bringing their ideas to life, while fashion designers use technology to create a variety of different accessories, such as: luggage, shoes, glasses and hats (LOPES, 2016).

### 1.5 Objective

The objective of this work is to review, analyse and classify the research carried out on 3D printing between the years 2014 and 2018. Thus, it is expected to understand in what way the researches are being carried out and what are the results achieved on the subject in recent years.

### 1.6 Justification

3D printing has great potential to positively impact manufacturing processes in the industrial sector. In this way, I believe that it is important that an analysis be done on the researches being carried out on the subject, showing their advances, benefits and points to be improved.

## II. METHODOLOGY

This chapter presents the two methods used to perform this work: journal selection, which describes the criteria for choosing periodicals and articles used; and classification of articles, which explains the 9 categories created to classify the selected articles.

### 2.1 Journals Selection

Through the CAPES Sucupira platform, a first search was made about periodicals from Engineering III (which is composed of Mechanical, Production, Aerospace and Naval). The other criterion used in the search was the relevance index, where we searched for the best articles in this question (in this case, the best articles are classified with the indexes A1, A2, B1 or B2). In this way, 21 journals were selected that had articles on Production and Manufacturing Engineering.

Using the keywords "3d printing" and "Project", searches were carried out in the 21 selected journals from 2014 to 2018. Thus, articles were found in 8 newspapers.

After analysing the selected articles, it was verified that some of them contained only brief quotations on the subject of rapid prototyping and therefore were discarded. Thus, the final selection is shown in Table 1.

*Table 1: Number of articles selected after review*

| REL. | Nº | JOURNAL | 2014 | 2015 | 2016 | 2017 | 2018 | TOTAL |
|---|---|---|---|---|---|---|---|---|
| | 1 | EUROPEAN JOURNAL OF OPERATIONAL RESEARCH | 0 | 0 | 0 | 0 | 1 | 1 |
| | 2 | INTERNATIONAL JOURNAL OF OPERATIONS & PRODUCTION MANAGEMENT | 0 | 0 | 0 | 0 | 1 | 1 |
| A1 | 3 | INTERNATIONAL JOURNAL OF PRODUCTION ECONOMICS | 1 | 1 | 0 | 2 | 7 | 11 |
| | 4 | JOURNAL OF ENGINEERING DESIGN | 0 | 0 | 1 | 1 | 2 | 4 |
| | 5 | CONCURRENT ENGINEERING: RESEARCH AND APPLICATIONS | 0 | 1 | 1 | 0 | 0 | 2 |

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| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 6 | INTERNATIONAL JOURNAL, ADVANCED MANUFACTURING TECHNOLOGY | 2 | 5 | 14 | 19 | 26 | 66 |
| **B1** | 7 | INTERNATIONAL JOURNAL OF COMPUTER INTEGRATED MANUFACTURING | 0 | 0 | 0 | 1 | 4 | 5 |
| | 8 | JOURNAL OF MANUFACTURING PROCESSES | 1 | 4 | 5 | 9 | 15 | 34 |
| | | **TOTAL** | 4 | 11 | 31 | 32 | 56 | 124 |

### 2.2 Articles Selection

The 124 selected articles were classified into 9 categories: study types, affiliation, approach, study origin, geographic coverage, unit of analysis, scope, benefits and negative points.

The category "types of study" refers to the way in which research is approached. Following the classification of Miguel (2007), the main types of research approach are:

- Conceptual theorist: new theories are developed through discussions of the existing literature;
- Case study: it is a more detailed analysis of one or more subjects or objects, aiming at their greater knowledge;
- Survey: Through a survey, you get information about a problem or object. Subsequently, an analysis of the collected data is made, in order to find a solution to the problem;
- Modelling and simulation: mathematical techniques or computer software are used to better understand a system;
- Action research: it is an empirical research where the researchers and interviewees seek to solve a given problem together;
- Literature review: study on a certain area of existing literature whose objective is to know and follow its development;
- Experimental research: it is the study about a system or object, where the researcher has control of one or more variables, manipulating them to observe what happens. The second category, "affiliation", aims to show what kind of institution is behind the research: university, research center or industry. The "approach" category analyses the data format used in the research: quantitative or qualitative. Next, the categories "origin of the study" and "geographic scope" are analysed, where they cover, respectively, in which continent the research was carried out and the scope of this study (regional, national or international).

The sixth category is the "unit of analysis", where the area in which the study was carried out is classified: Application in companies or academic projects in the areas of costs, design, production or product quality; study of theoretical model; social impact; equipment (hardware, software or process).

The seventh category, "scope", contemplates the subject studied by the article, while the last two categories classify the "benefits" and "negative points" found by the researchers.

In Annex I, you will find all the classifications mentioned above, as well as their captions. In Annex II, the classifications of the 124 analysed articles are detailed, according to the captions in the tables in Annex I.

## III. RESULTS AND DISCUSSION

In this chapter the results obtained will be shown and analysed in the last section of the chapter. Firstly, the data of the publication numbers of the articles selected between the years 2014 and 2018 will be shown. After that, the data of each of the 9 categories mentioned in the methodology will be shown. In the final item, the results will be discussed.

### 3.1 Number of Article Publications about 3D Printing

Fig. 1 shows the percentage of articles published in the selected journals between the years 2014 and 2018. The small number of articles on rapid prototyping in the years 2014 and 2015 can be perceived, with the increase of these numbers in the following years, year of 2018, with 41.79% of articles released.

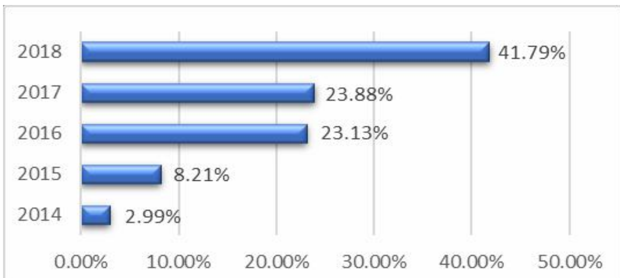


*Fig. 1: Percentage distribution of articles published per year.*

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### 3.2 Types of Study

Fig. 2 shows the distribution of the types of studies performed. It was verified that the research study of the case was the most accomplished, with 61.3%. It is followed by far by experimental research, with 22.6%. Literature review, action research, modelling and simulation, survey and conceptual theorist obtained less than 10%, and action research was not performed once.

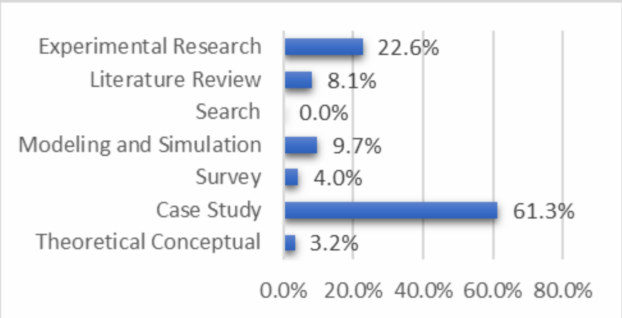


*Fig. 2: Classification by type of study performed.*

### 3.3 Affiliation

In order to carry out this classification, only the main author of each article was considered. Thus, although there were contributions from individuals linked to private industries and research centers, it was considered that 100% of the articles were carried out through universities, due to the fact that all the leaders of the articles are linked to institutions of teaching.

### 3.4 Approach

Fig. 3 shows the type of approach performed in the selected works, being it quantitative or qualitative. According to the figure below, 79.8% of the cases adopted are quantitative.

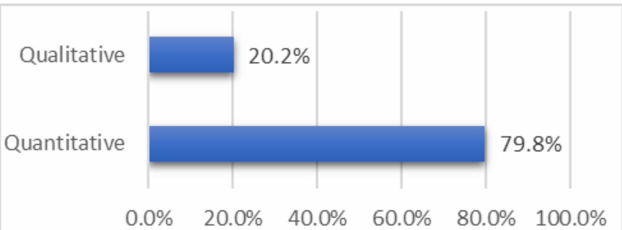


*Fig. 3: Classification by approach.*

### 3.5 Origin of Study

Fig. 4 classifies the origin of the articles. Asia and Europe lead the number of publications with 32.3% each. While the countries of the Americas (the only countries cited were the United States and Canada) published 25.8%. Oceania and Africa reached 4.8% and 2.4%, respectively, while Brazil also published 2.4% of the articles.

Even if the comparison between Brazil versus whole continents is somewhat unfair, the ideal would be that the number of relevant Brazilian research in the international scenario will grow in the coming years.

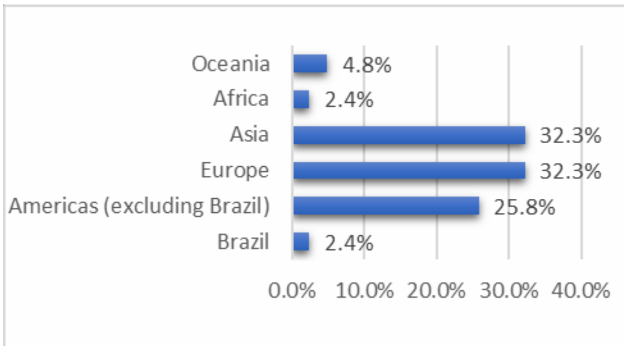


*Fig. 4: Classification by origin*

### 3.6 Geographical Scope

Fig. 5 classifies the articles by means of the geographical scope of the articles, that is, what territory was taken into account in their research (regional, national or international level). Only 11 of the 124 selected articles were found, and in 63.6% of these 11 articles, they were classified as international coverage and the other 36.6% as a national coverage.

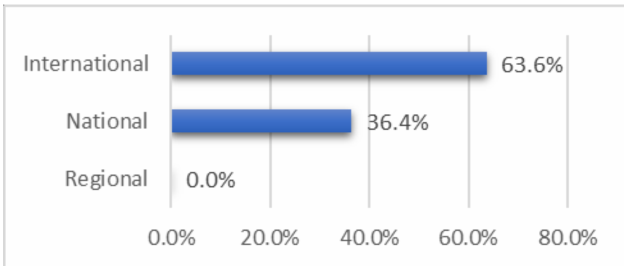


*Fig. 5: Classification by geographic scope.*

### 3.7 Unit of Analysis

Fig. 6 shows the unit of analysis data, that is, the area in which the search was performed. They were classified into 5 main groups, 4 of which have subgroups:

- Improvement in fast prototyping equipment (53.2%), being subdivided into process (33.1%), hardware (4.8%) and software (15.3%);
- Application in academic projects (37%), being subdivided into product quality (18.5%), production (11.3%), design (5.6%) and costs (1.6%);
- Application in companies (29.1%), being subdivided into product quality (3.2%), production (12.1%), design (6.5%) and costs (7.3%);
- Social Impact (1.6%), being subdivided into education (0%) and environmental (1.6%);
- Study of theoretical model (5.3%).

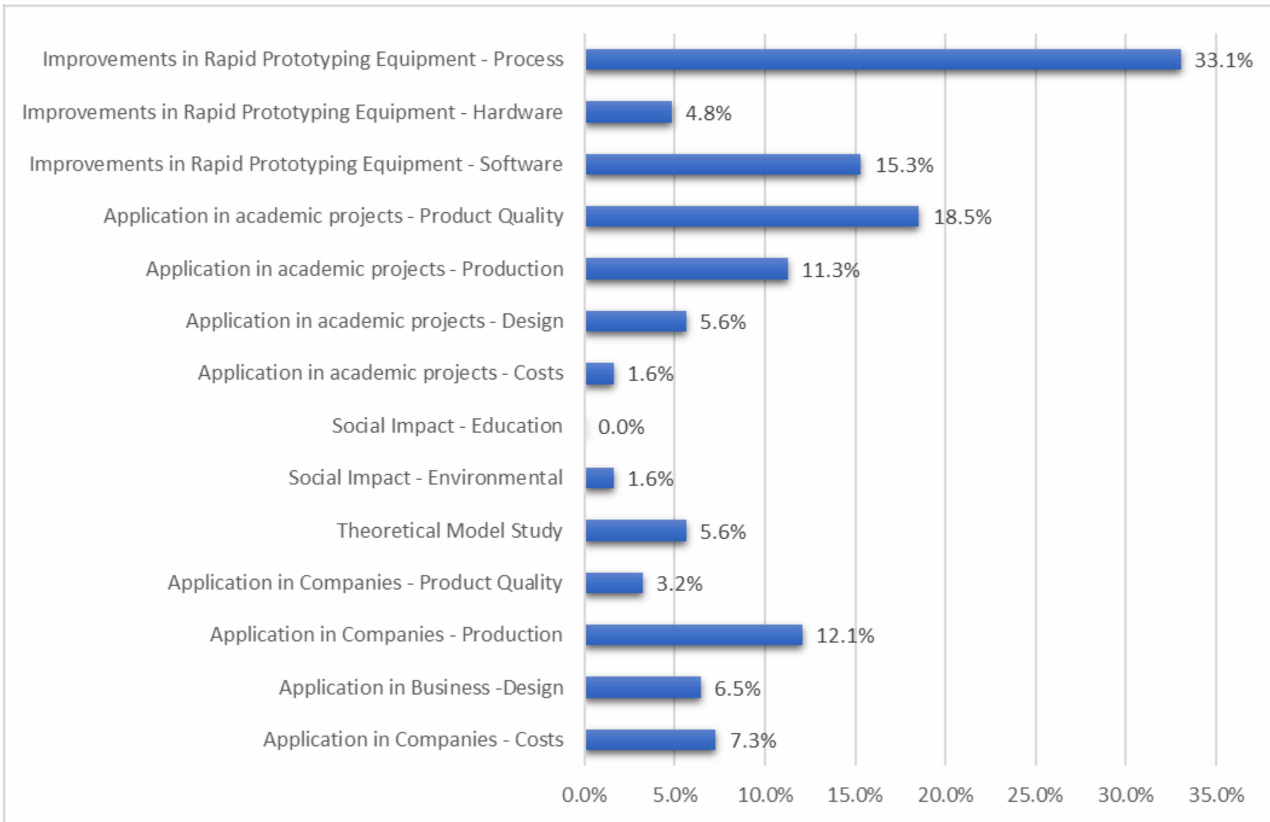


*Fig. 6: Classification by unit of analysis.*

### 3.8 Scope

Fig. 7 shows the scoped classification of articles. 62.1% of the articles refer to product development (it was considered as product development: manufacture of parts via additive manufacture and improvements related to the "product" 3D printer), followed by a 21.8% impact of rapid prototyping and 12.1% to implementation strategies. The other items have less than 10%.

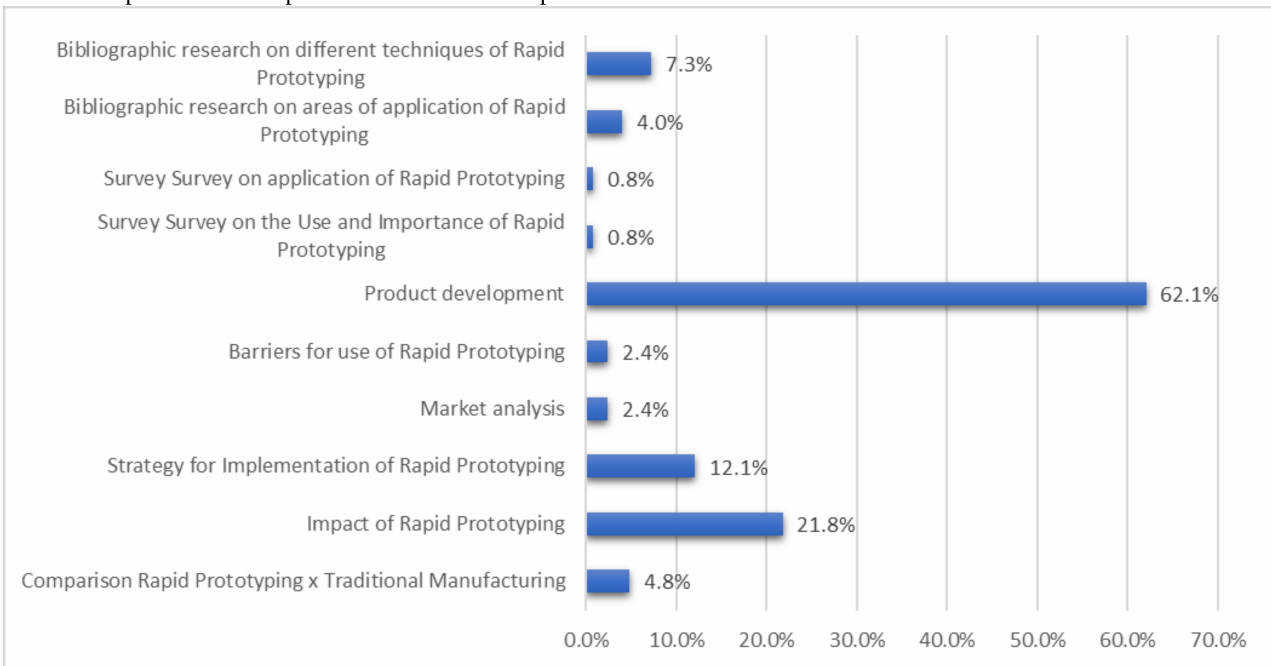


*Fig. 7: Scope classification.*

### 3.9 Benefits

Fig. 8 shows the benefits that rapid prototyping can provide. Of the 124 articles selected, 73 of them have verified one or more contributions. The contributions were classified into 8 different types, and the item "higher quality" appears in 38.7% of the articles. Improved design, lead-time reduction and lower cost represent 16.9%, 14.5% and 12.1% respectively. The benefits of flexible manufacturing process, lower material waste, lower environmental impact and increased product life span appear with less than 5% each.

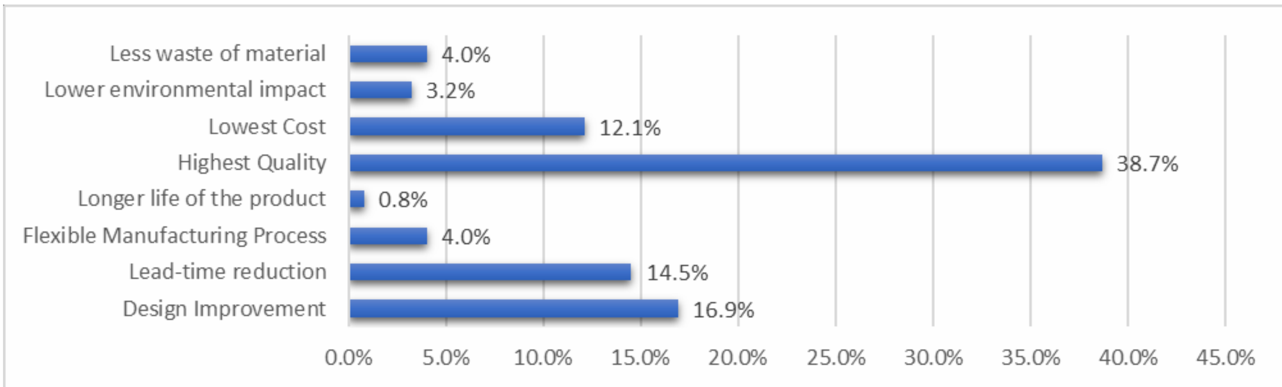


*Fig. 8: Classification by benefits.*

### 3.10 Pontos Negativos

Fig. 9 shows the negatives of rapid prototyping. Of the 124 articles selected, only 13 of them pointed out at least 1 item to improve. The highlights are the items higher cost and difficulty of large-scale production, with 30.8% each and the items limited raw material and low reliability/quality of the product with 23.1% each.

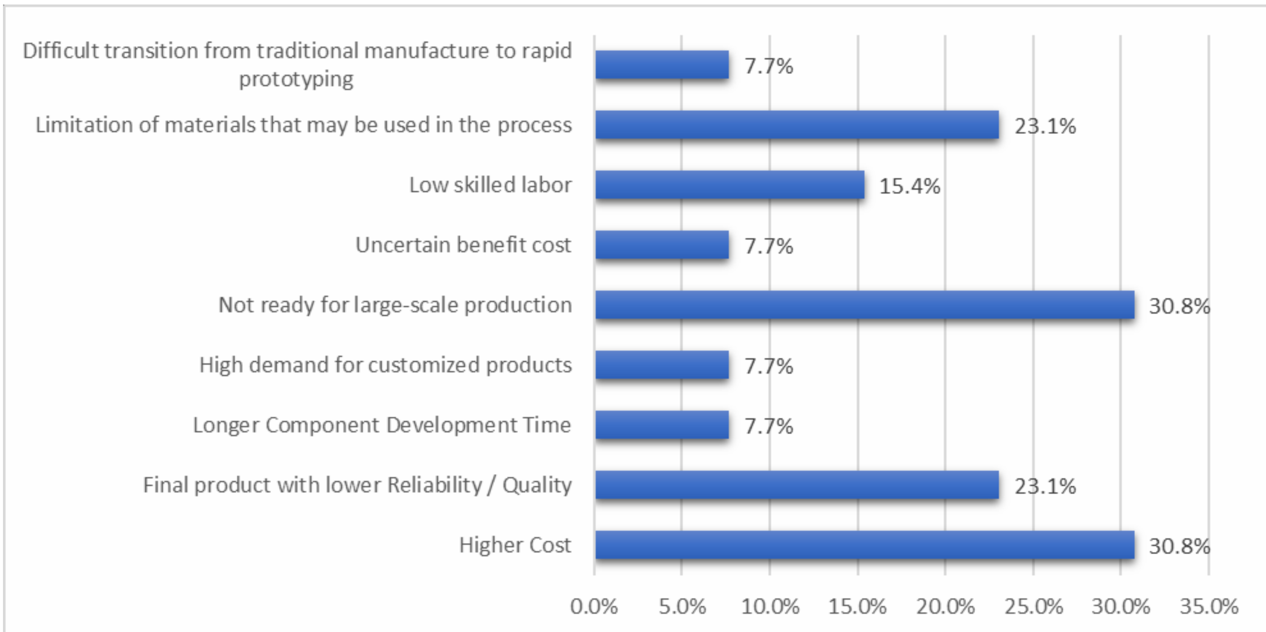


*Fig. 9: Classification by negative points.*

### 3.11 Data Analysis

Levando em consideração os dados apresentados nos itens anteriores pode-se dizer que:

1. The number of surveys with a high degree of relevance on 3D printing has been increasing year after year. This indicates that the theme's importance and popularity have been growing and are seeking new ways to improve technology;
2. Although some studies are conducted exclusively for the purpose of studying the market or solving problems of private initiative, it is universities that conduct research in this area;

3. Europe and Asia are the continents that have published articles with a high degree of relevance about additive manufacturing;
4. Case study and experimental research were the two types of studies most performed within the analysed article sampling;
5. About 50% of articles aim to contribute to the improvement in 3D printing equipment (software, hardware or process), however, there are few articles related to the theme related to social impact;
6. 60% of the articles selected have as scope the development of a product;
7. Of the 124 papers analysed, 73 of them observed some benefit that 3D printing provided, being that higher quality, better design, reduction of lead-time and lower cost, were the qualities most cited. Meanwhile, only 13 articles mentioned some negative point regarding the additive manufacture, being lack of preparation for large- scale production and higher cost the two most cited damages.

## IV. CONCLUSION

Through the data analysed, it can be concluded that 3D printing is increasingly being studied, which indicates the importance and popularity of the theme. Of the 124 articles selected, 2.99% of them were published in 2014, 8.21% in 2015, 23.13% in 2016, 23.88% in 2017 and 41.79% in 2018. Taking into account the category affiliation, all articles were classified as university students, that is, the research was led by professionals linked to higher education institutions. Taking into account the origin of the articles produced, it was verified that the majority are from Asia and Europe (32.2% produced in each continent, totalling 64.4%). Regarding the unit of analysis, the highlight was the improvement of equipment with a focus on process (33.1%) and, in article scope, the product development item was the most cited (62.1%). Finally, in the categories of benefits and negatives of 3D printing, the highlights were the higher quality of the product (38.7%) and higher cost and lack of capacity for high-scale production, with 30.8% for each of the items.

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## ANNEX I: Classification Tables for Articles

*Table 1: Articles classification by types of study.*

| LABEL | T1 : Types of Study |
|---|---|
| A | Theoretical Conceptual |
| B | Case Study |
| C | Survey |
| D | Modeling and Simulation |
| E | Search |
| F | Literature Review |
| G | Experimental Research |

*Table 2: Articles classification by affiliation.*

| LABEL | T2: Affiliation |
|---|---|
| U | University |
| CP | Research Center |
| EP | Company |

*Table 3: Articles classification by affiliation.*

| LABEL | T3: Approach |
|---|---|
| A | Quantitative |
| B | Qualitative |

*Table 4: Articles classification by study origin.*

| LABEL | T4: Origin |
|---|---|
| BR | Brazil |
| AM | Americas (excluding Brazil) |
| EU | Europe |
| AS | Asia |
| AF | Africa |
| OC | Oceania |

*Table 5: Articles classification by geographical scope of the study.*

| LABEL | T5: Geographical scope of study |
|---|---|
| RE | Regional |
| NA | National |
| IN | International |

*Table 6: Articles classification by unit of analysis.*

| LABEL | T6: Analysis Unit |
|---|---|
| EC | Application in Companies - Costs |
| ED | Application in Business -Design |
| EP | Application in Companies - Production |
| EQ | Application in Companies - Product Quality |
| MT | Theoretical Model Study |
| ISA | Social Impact - Environmental |

| | |
|---|---|
| ISE | Social Impact - Education |
| UC | Application in academic projects - Costs |
| UD | Application in academic projects - Design |
| UP | Application in academic projects - Production |
| UQ | Application in academic projects - Product Quality |
| MS | Improvements in Rapid Prototyping Equipment - Software |
| MH | Improvements in Rapid Prototyping Equipment - Hardware |
| MP | Improvements in Rapid Prototyping Equipment - Process |

*Table 7: Articles classification by scope.*

| LABEL | T7: Scope of the article |
|---|---|
| A1 | Comparison Rapid Prototyping x Traditional Manufacturing |
| A2 | Impact of Rapid Prototyping |
| A3 | Strategy for Implementation of Rapid Prototyping |
| A4 | Market analysis |
| A5 | Barriers for use of Rapid Prototyping |
| A6 | Product development |
| A7 | Survey Survey on the Use and Importance of Rapid Prototyping |
| A8 | Survey Survey on application of Rapid Prototyping |
| A9 | Bibliographic research on areas of application of Rapid Prototyping |
| A10 | Bibliographic research on different techniques of Rapid Prototyping |

*Table 8: Articles classification by benefits.*

| LEGENDA | T8: Benefits |
|---|---|
| B1 | Design Improvement |
| B2 | Lead-time reduction |
| B3 | Flexible Manufacturing Process |
| B4 | Longer life of the product |
| B5 | Highest Quality |
| B6 | Lowest Cost |
| B7 | Lower environmental impact |
| B8 | Less waste of material |

*Table 9: Articles classification by negative points.*

| LEGENDA | T9: Negative points |
|---|---|
| C1 | Higher Cost |
| C2 | Final product with lower Reliability / Quality |
| C3 | Longer Component Development Time |
| C4 | High demand for customized products |
| C5 | Not ready for large-scale production |
| C6 | Uncertain benefit cost |
| C7 | Low skilled labor |
| C8 | Limitation of materials that may be used in the process |
| C9 | Difficult transition from traditional manufacture to rapid prototyping |

**ANNEX II: Selected Articles Classification**

*Table 1: Classification of articles by type of study.*

| Journal | Authors | T1 | T2 | T3 | T4 | T5 | T6 | T7 | T8 | T9 |
|---|---|---|---|---|---|---|---|---|---|---|
| **1** | Westerweel et al. (2018) | B | U | A | EU | IN | EC,ED,EQ | A1 | B1,B2 | C1,C2 |
| **2** | Eyers et al. (2018) | B | U | B | EU | IN | EP | A2 | B3 | |
| **3** | Melor et al. (2014) | B | U | B | EU | IN | EP | A3 | B2,B4 | C3 |
| **3** | Weller et al. (2015) | A,F | U | B | EU | | MT | A2 | B1,B2,B3 | C4 |
| **3** | Schniederjans (2017) | C | U | A | AM | NA | EC,ED,EP | A7 | B2,B5 | |
| **3** | Hartl & Kort (2017) | B | U | A | EU | | MT | A4 | | |
| **3** | Chan et al. (2018) | C | U | B | AS | IN | EC,ED,EP | A8 | | C5 |
| **3** | Thomas-Seale et al. (2018) | B,C | U | A | EU | NA | EC | A4, A5 | | C2,C5,C6, C7,C8 |
| **3** | Ghobadian et al. (2018) | B | U | B | EU | | EC,ISA | A2 | B6,B7,B8 | C5 |
| **3** | Chekurov et al. (2018) | C | U | B | EU | NA | ED,EP,EQ | A3 | B1,B2,B5,B6 | |
| **3** | Knofius et al. (2018) | B | U | A | EU | | ED,EP,EQ,EP | A3 | B2,B5,B6 | C9 |
| **3** | Caviggioli & Ughetto (2018) | F | U | A | EU | IN | EC,ISA | A9 | | |
| **3** | Yang & Lin (2018) | D | U | A | AM | | MT | A2 | B1,B6 | |
| **4** | Lei et al. (2016) | B | U | A | AS | | UQ | A1, A2 | B1 | |
| **4** | Lockett et al. (2017) | B | U | A | EU | | UQ | A2 | B1,B8 | |
| **4** | Pradel et al. (Jun, 2018) | B | U | B | EU | | ED | A9 | | |
| **4** | Pradel et al. (Mar, 2018) | C | U | B | EU | IN | ED | A2 | B1 | C1 |
| **5** | Ravn et al. (2015) | D | U | B | EU | NA | MS | A2 | B1 | |
| **5** | Mawale et al. (2016) | B | U | B | AS | | EC,ED,EQ | A2 | B1,B5,B6 | |
| **6** | Xiao et al. (2014) | B,D,G | U | A | EU | | UQ,UD,UC | A2,A6 | B1,B2,B5,B6 | |

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| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **6** | Espalin et al. (2014) | B,G | U | A | AM | | UQ,UP | A2,A6 | B1 | |
| **6** | Monzón et al. (2015) | B | U | B | EU | | EP | A3,A5 | | C7,C8 |
| **6** | Vijayaraghavan et al. (2015) | D | U | A | AS | | MS | A2 | B1,B5 | |
| **6** | Jiang et al. (2015) | D,G | U | A | AS | | MP | A2,A6 | B5 | |
| **6** | Mançaneres et al. (2015) | B | U | A | BR | | UQ | A2,A6 | | |
| **6** | Yang & Zhao (2015) | A | U | B | AM | | MT | A2,A6 | | |
| **6** | Kantaros et al. (2016) | G | U | A | EU | | MH | A6 | B5 | |
| **6** | Bikas et al. (2016) | F | U | B | EU | | MT | A10 | | |
| **6** | Mai et al. (2016) | B | U | B | AS | | EP | A2 | B2,B3,B6,B7 | |
| **6** | Li et al. (2016) | A | U | A | AS | | UQ | A6 | B5 | |
| **6** | Alberti et al. (2016) | G | U | A | BR | | MP | A2 | B5 | |
| **6** | Yang & Lin (2016) | G | U | A | AS | | MP, UQ | A2,A6 | B5 | |
| **6** | Yao & Lin (2016) | B | U | B | AS | | EP | A3 | B3 | |
| **6** | Laplume et al. (2016) | B | U | A | AM | | EC, EP | A4 | | |
| **6** | Mandil et al. (2016) | B | U | A | EU | | MP | A2 | B5 | |
| **6** | Ali et al. (2016) | G | U | A | AS | | MH, MP | A2 | B6 | C5 |
| **6** | Wang et al. (Set,2016) | B | U | A | AS | | UQ | A6 | B5 | |
| **6** | Papazetis & Vosniakos (2016) | B | U | A | EU | | UQ | A6 | B5 | |
| **6** | Kamath (2016) | G | U | A | AM | | MS | A2 | B5 | |
| **6** | Salonitis (2016) | B | U | B | EU | | UD | A3 | | |
| **6** | Islam et al. (2017) | B | U | A | OC | | UQ | A10 | | |
| **6** | Romero et al. (2017) | B | U | B | EU | | MP | A2,A6 | | |
| **6** | Panda et al. (2017) | B | U | A | EU | | UQ | A10 | | |
| **6** | Brooks et al. | G | U | A | OC | | MP | A2,A6 | | |

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| | (2017) | | | | | | | | | |
| **6** | Monzón et al. (2017) | G | U | A | EU | | MP | A2,A6 | B1,B5 | |
| **6** | Liu et al. (2017) | G | U | A | AS | | MP | A2,A6 | B5 | |
| **6** | Garg et al. (2017) | G | U | A | AS | | MP | A2,A6 | B5 | |
| **6** | Chen et al. (2017) | B | U | B | AS | | EP | A3,A5 | | C1,C8 |
| **6** | Urbanic et al. (2017) | B | U | A | AM | | EP | A3 | | |
| **6** | Ferreira et al. (2017) | G | U | A | OC | | MS, MH | A6 | B5 | |
| **6** | Mohiuddin et al. (2017) | B,D | U | A | AS | | UQ | A6 | B5 | |
| **6** | Tavakoli et al. (2017) | B | U | A | EU | | UD | A6 | B5 | |
| **6** | Hsu et al. (2017) | B,D | U | A | AS | | UP, UQ | A6 | B5,B6 | |
| **6** | Sasaki et al. (2017) | D | U | A | AS | | MS | A6 | | |
| **6** | Baumann et al. (2017) | B | U | B | EU | | UP | A3 | | |
| **6** | Snelling et al. (2017) | B | U | A | AM | | MP | A6 | B5 | |
| **6** | Leal et al. (2017) | B | U | A | EU | IN | EP,EC | A1,A3,A6 | B2,B6 | |
| **6** | Jin et al. (2017) | B | U | A | AS | | MS | A6 | B1 | |
| **6** | Primo et al. (2017) | B | U | A | EU | | UD, UP | A6 | B5 | |
| **6** | Goh et al. (2018) | B | U | A | AS | | UQ | A10 | B5 | |
| **6** | Yaman (2018) | B | U | A | EU | | MS, MP | A6 | B5,B8 | |
| **6** | Feng et al. (2018) | B | U | A | AS | | UP | A6 | B1,B6 | |
| **6** | Khorasani et al. (2018) | B | U | A | OC | | UD,UP | A6 | B1 | |
| **6** | Li et al. (Mar, 2018) | B | U | A | AS | | MS, MP | A6 | B1,B5 | |
| **6** | Chong et al. (2018) | F | U | B | AS | | UD,UP | A10 | | |
| **6** | Zhang et al. (Mar, 2018) | B | U | A | AS | | MS | A6 | B2 | |
| **6** | Lee et al. (2018) | D | U | A | AM | | MP | A6 | | |
| **6** | Jaiswal et al. | B | U | A | AM | | MS | A6 | B2 | |

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| | (2018) | | | | | | | | |
| **6** | Li et al. (May, 2018) | G | U | A | AS | | MP | A6 | B5 |
| **6** | Guo & Qiu (May, 2018) | F | U | B | AS | | UP | A3 | |
| **6** | Shangguan et al. (2018) | G | U | A | AS | | MP | A6 | B2,B5 |
| **6** | Zhao et al. (2018) | B,D | U | A | AS | | MS | A6 | B2 |
| **6** | Chai et al. (2018) | B | U | A | OC | | UC,UP,UQ | A6 | B2, B5, B6 |
| **6** | Asadollahi-Yazdi et al. (2018) | B | U | A | EU | | UP | A3,A6 | |
| **6** | Tang et al. (2018) | G | U | A | AS | | MP | A6 | B5,B7 |
| **6** | Hawaldar et al. (2018) | B | U | A | AM | | UQ | A1 | B2,B5,B8 |
| **6** | Bahnini et al. (2018) | F | U | B | AF | | EP | A1,A2,A9,A10 | |
| **6** | Lebedev et al. (2018) | B | U | A | EU | | MS | A6 | B5 |
| **6** | Baturynska (2018) | D | U | A | EU | | UQ | A6 | C1 |
| **6** | Tronvoll et al. (2018) | B | U | A | EU | | MS, UQ | A6 | B5 |
| **6** | Pereira et al. (2018) | B | U | A | EU | | MS, UQ | A6 | B5 |
| **6** | Wang & Dommati (Set, 2018) | G | U | A | AS | | MP | A6 | B5 |
| **6** | Pires et al. (2018) | G | U | A | EU | | MP | A6 | B5 |
| **6** | Bruna-Rosso et al. (2018) | G | U | A | EU | | MP | A6 | B5 |
| **6** | Imeri et al. (2018) | B | U | A | AM | | UQ | A6 | |
| **7** | Jin et al. (2017) | B | U | A | AS | | MS | A6 | B1,B2,B5 |
| **7** | Sunny et al. (2018) | B | U | B | AM | | UP | A3 | |
| **7** | Helou & Kara (2018) | F | U | B | OC | | UD,UP | A9 | |
| **7** | Charro & Schaefer (2018) | B | U | A | EU | | MP | A3 | B3, B6 |
| **7** | Bonnard et al. (2018) | A | U | A | BR | | MS | A6 | |

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| **8** | Wei & Dong (2014) | B | U | A | AM | | MS | A6 | B5 | |
| **8** | Han et al. (2015) | B | U | A | AM | | MP | A6 | | |
| **8** | Mun et al. (2015) | D | U | A | AS | | MP | A6 | | |
| **8** | Brant & Sundaram (2015) | B | U | A | AM | | MP | A3 | B2 | |
| **8** | Zha & Anand (2015) | B | U | A | AM | | MS | A6 | B1,B5 | |
| **8** | Ravi et al. (2016) | B | U | A | AM | | MP | A6 | B5 | |
| **8** | Dawoud et al. (2016) | B | U | A | AF | | UQ | A1 | | C2 |
| **8** | Kim & Tai (2016) | B | U | A | AM | | MP | A6 | | |
| **8** | Correa et al. (2016) | B | U | A | AM | | MH | A6 | | |
| **8** | Mao et al. (2016) | B | U | A | AM | | MP | A6 | B1,B5 | |
| **8** | Habib & Khoda (2017) | B | U | A | AM | | MP | A6 | B1,B2,B5 | |
| **8** | Upadhyay et al. (2017) | F | U | A | EU | | UP | A10 | | |
| **8** | Jin & Chen (2017) | B | U | A | AM | | MH | A6 | | |
| **8** | Fang et al. (2017) | B | U | A | AS | | MP | A6 | B6 | |
| **8** | Estelle et al. (2017) | B | U | A | AM | | MP | A6 | B5 | |
| **8** | Liu et al. (2017) | B | U | A | AS | | MH | A6 | B5 | |
| **8** | Sheydaeian & Toyserkani (2017) | B,G | U | A | AM | | MP | A6 | | |
| **8** | Areir et al. (2017) | B | U | A | EU | | MP | A6 | | |
| **8** | Singh et al. (2017) | F | U | B | AS | | MT | A9,A10 | | |
| **8** | Khodabakhshi & Gerlich (2018) | F | U | A | AM | | MT | A10 | | |
| **8** | Du et al. (2018) | B | U | A | AS | | MP | A6 | | |
| **8** | Alaboodi & Sivasankaran (2018) | B | U | A | AS | | MP | A6 | B5 | |
| **8** | Kumar et al. (2018) | B | U | A | AS | | MH | A6 | B5 | |
| **8** | Kumar et al. (2018) | B | U | A | AS | | UQ | A6 | | |
| **8** | Dawoud et al. (2018) | B | U | A | AF | | UQ | A6 | | |

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| **8** | Jabbari & Abrinia (2018) | B,G | U | A | AS | | MP | A6 | | |
| **8** | Duty et al. (2018) | B | U | A | AM | | MP | A6 | | |
| **8** | Jin et al. (2018) | G | U | A | AM | | MP | A6 | | |
| **8** | Kumar (2018) | G | U | A | AM | | MP | A6 | | |
| **8** | MacDonald et al. (2018) | G | U | A | AM | | UP | A6 | | |
| **8** | Li et al. (2018) | G | U | A | AM | | MP | A6 | B6,B7,B8 | |
| **8** | Kitayama et al. (2018) | G | U | A | AS | | MS | A6 | | |
| **8** | Bournias-Varotsis et al. (2018) | G | U | A | EU | | MP | A6 | | |
| **8** | Holt et al. (2018) | G | U | A | AM | | MP | A6 | | |