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THE LEAN STARTUP APPROACH IN THE MANUFACTURED PRODUCTS DEVELOPMENT PROCESS: A SYSTEMATIC REVIEW

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Abstract. *The Lean Startup approach is an agile model widely used in enterprises of software development, being reported positive results. However, since despite being mentioned as a possibility, the use of this approach in manufactured product development still is a problem. Therefore, this article seeks to analyze the scientific production about the use of the Lean Startup approach in the manufactured product development process, delimiting the state of art and proposing new directions to expand the knowledge's frontier. A systematic bibliographic review was carried out and 121 articles were collected, of which 16 were selected after the filtering process. Was noted that the approach is not applied alone, but together with other practices and tools for development, and despite were reported benefits for PDP using practices of the Lean Startup approach, how to apply and manage this application in the field of manufactured products are not topics discussed in bibliographic. Also are not reported the main challenges of this application. Furthermore, an indication was obtained regarding the need to improve traditional development methodologies towards agile development. The potential of the theme was realized and the different research possibilities on the subject were reported.*

Keywords: *Lean Startup, Product Development Process, Manufactured Products, Hardware.*

1. INTRODUCTION

The products and services market have lived in an environment of high uncertainty, so to remain competitive, is essential that companies seek to minimize risks within their businesses, striving to continuously improve the internal performance and quality of the products. An important aspect of this theme is related to the product development process (PDP).

It is quite common for project teams to make use of reference models and management practices during development (De Paula and Mello, 2013), however, despite being widely used, the traditional methodologies generally have limitations because they work with very bureaucratic processes and verifications in long cycles. Therefore, they have been considered not very flexible and even rigid when applied in dynamic markets, like the actual (Cooper and Sommer, 2018). As a counterpoint to these methodologies, agile development models emerged.

In the field of information technology (IT) the use of agile models is already consolidated, however, the application of their concepts in other contexts, such as in manufactured product industries (or to hardware development), is still very recent (Conforto *et al.*, 2014; Cooper and Sommer, 2016).

An agile development approach that has been standing out is Lean Startup, with positive results reported from its use, such as acceleration of learning and customer feedback, reduction of uncertainties, and the development of products focused on real value. This approach is related to the lean concept and is based on continuous learning and frequent interaction and communication between developers, customers, and other stakeholders, focusing on the development and verification in short cycles (Ries, 2012).

Despite the Lean Startup approach have been arising within the scope of software startups, the use of their concepts can exceed these limits, being also applied within large corporations in any sector or activity (Edison *et al.*, 2015; Ries, 2012). However, its application for the development of manufactured products is still an issue to be addressed, since although this possibility is mentioned, in practice it is not known how the Lean Startup approach can be applied and managed in these environments. Thus, this article aims to analyze the scientific production about the use of the Lean Startup approach in the development of manufactured products, defining the state of the art and, from this, propose new directions for the expansion of the knowledge frontier.

2. THE LEAN STARTUP

The Lean Startup approach was created by Ries (2012), having its roots in lean production, proposed by Taiichi Ohno and Shigeo Shingo at Toyota Motor Company. One of the bases of the Toyota Production System is the elimination of waste in its various forms, believing in the importance of valuing and developing its employees (Ohno, 1997), which is also present in the Lean Startup approach. In addition, one of the most relevant points of the approach is related to a visceral integration with customers, based on the "get out of the building" idea: whoever is developing a product or service needs intense and extensive contact with the possible customers to truly understand them, and this happens outside the development office (Ries, 2012; Blank and Dorf, 2014; Maurya, 2012).

The Lean Startup approach cannot be treated as a set of techniques, but as an approach with principles to develop new products, being them (Ries, 2012):

a. Entrepreneurs are everywhere, so the Lean Startup approach can work in organizations of any size and sector;
b. Entrepreneurship should be treated like a way to administer. As a startup is an institution, it requires a new form of management, which works in contexts of extreme uncertainty;
c. Learning must be validated and one form of doing this is using frequent scientific experiments;
d. All the processes of the startup need to be realized according to the build-measure-learn cycle, in which ideas are transformed into a product, the reactions of the clients are measured and learnings are obtained from that;
e. Tracking a startup's progress requires a new form of accounting - accounting for innovation - which must be different from traditional accounting.

Among the principles cited, the third and fourth stand out. The build-measure-learn cycle (BML), also called the feedback cycle, is the central part of the Lean Startup model; based on this cycle the scientific experiments mentioned in the fourth principle are formulated and executed. In addition, this feedback cycle must be carried out in such a way that it seeks to minimize the total time spent on learning (Ries, 2012). The BML cycle model is shown in Figure 1.

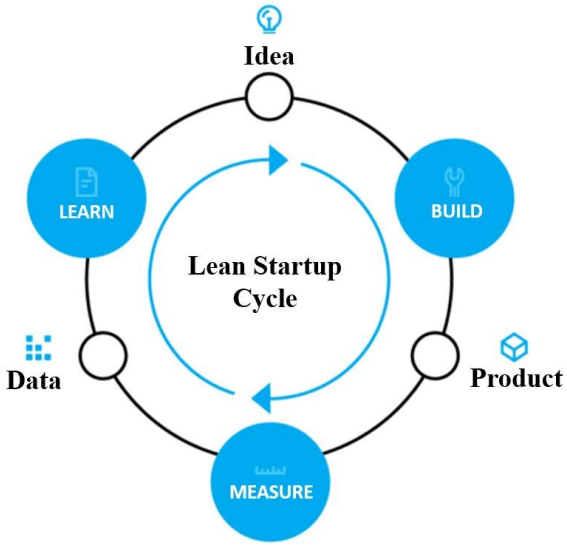

Figure 1. The feedback cycle of the Lean Startup approach (adapted from Pereira, 2019).

The "build" phase of the cycle begins with an idea, which at Lean Startup is closely linked to the concept of hypotheses. Assumptions are made and hypotheses are created, based on a vision, that needs to be "built" and tested. This construction is often related to the idea of a minimum viable product (MVP), mainly in the product development phase. The MVP is a minimum version of the product, which brings the basic ideas of operation and can be tested in some way, allowing a complete return to the feedback cycle, with the lowest level of effort and development time (Ries, 2012). According to Blank and Dorf (2014), the MVP helps the team to focus on the most important features of the product and aims to be a means of identifying whether the customer's problems were truly understood and whether it was possible to define the essential elements to solve them.

There are many types of MVP that vary according to what you are trying to learn (Ries, 2018), which may differ according to the investment required, hypothesis to be tested, level of detail, type of product to be developed, and stage of the product design. MVPs can range from a sketch depicting the workings of something, even a more elaborate prototype, as long as their performance can be measured in some way.

Another important point regarding the first stage of the cycle is that, although it is often associated with the development phase and the exit from that phase of the cycle is called "product", it is not only related to the construction of physical objects. The feedback cycle happens in all processes within a Lean Startup, and thus it also occurs in the most initial phase of its development - such as, for example, in the phase of getting to know potential customers. For use in these cases, the construction of something necessarily physical may not be the most appropriate way to test a hypothesis.

The concept is not obligatorily to build a product, or even to ask customers directly what they want, but to design an experiment in which it is possible to find out as soon as possible which hypotheses are true and which are not (Ries, 2018).

For an experience to be promising, it needs to be built on important resources, not just "to see what happens". The experiments must have a clear and verifiable vision, that is, they must have an expected result, and because they are inserted within the feedback cycle, each experiment must lead to a subsequent action - a single experiment is not enough. Still, it is important to have a strict containment of the risks in each experiment, that is, it is necessary to know the worst that can happen due to this experience and to make sure that the result can be tolerated. Finally, experiments must be performed to test assumptions, so it must be possible to link what is being measured in the experiment with at least one hypothesis (Ries, 2018).

The measuring phase of the cycle is associated with the knowledge of the progress being made. It is a stage that requires great care by the development team, since it is here that the vanity metrics can appear, which according to Ries (2012) are usually gross metrics or cumulative totals, such as the total number of customers using the product or total revenue, which can often make appear an illusory reality.

The analyzed metrics in this phase must be established still in the previous phase, in the formulation of the experiment, and its need to be actionable, accessible, and auditable. An actionable metric is characterized by the demonstrations of cause and effect, while an accessible metric is related not just to accessibility, which must be guaranteed to everyone involved in the project, but mainly with the ease of interpretation of the data. An example of the use of an accessible metric is an experiment report prepared in the simplest way possible, using tangible units and being made available practically and quickly to those involved. Finally, the metrics must be auditable, that is, the results of these metrics must come from reliable sources that can be tested and confirmed (Ries, 2018).

Lastly, there is the validated learning phase of the cycle. In this, the data obtained in the previous phase are evaluated, making it possible to discover which hypotheses raised are confirmed and which are not. At this phase, one of the most difficult issues within a startup arises - changing course. Depending on the results obtained, the team must decide whether to pivot or persevere in the previous idea, starting the creation of new hypotheses and restarting the feedback cycle (Ries, 2012; Ries, 2018).

The concept of pivoting, according to Ries (2012), can be understood as a change in strategy, without changing the vision. Other authors agree with the idea of pivoting pointed by Ries, as is the case of Bajwa *et al.* (2016 apud Moreira, 2019), who argue that the pivot is a significant change in one or more elements of the startup (product, customers, team, among others), but not in all. Changing all the elements of the startup would be the proposition of an enterprise new.

Still regarding pivoting, Maurya (2012) considers the pivot as a form of correction, in which the intention is to validate new hypotheses of a model to find a "working plan" for the enterprise. A simplified structure of how the Lean Startup approach works based on the idea of vision and bringing together the phases of the build-measure-learn cycle with the concepts of pivoting and persevering is shown in Figure 2.

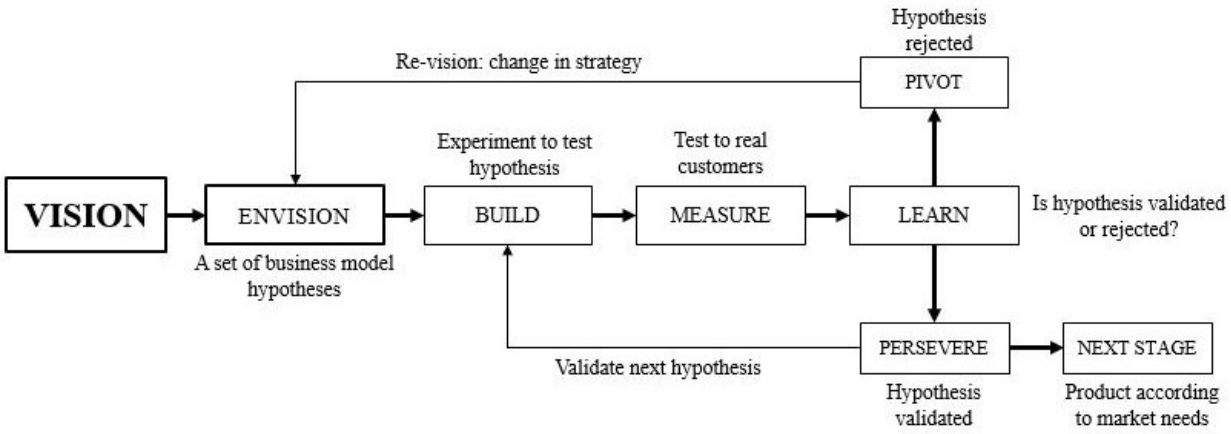

Figure 2. Simplified structure of the Lean Startup approach (adapted from Edison, 2015 apud Edison *et al.*, 2018).

3. METHODOLOGY

Initially, a systematic literature review was carried out to gather scientific production about the use of the Startup Lean approach in the development of manufactured products. To carry out this review, the Systematic Search Flow (SSF) method by Ferenhof and Fernandes (2016) was followed.

Four different databases were used: Scopus, Engineering Village, Ebsco, and Web of Science, and the search was done by the title, abstract, and keywords, using the following search string: (("lean startup" OR "build-measure-learn"

OR "feedback cycle" OR "hypothesis creation" OR "hypothesis elaboration") AND ("product development" OR "design process" OR "product design" OR "physical product*" OR "manufactur*" OR hardware) AND NOT "software").

The definition of the string was performed by testing an initial string, which took into account the most important words related to the subject. From the studies found and the keywords cited the string was being adapted. Regarding the logical connectors, they were tested in the different databases, to verify the existence of inconsistencies. Also, the databases were defined taking into account the engineering area, the acceptance of the use of different logical operators and special characters, and the possibility of extracting information for bibliometric analysis.

Were filtered documents such as articles, reviews, conference papers, and conference reviews, in English or Portuguese, that contained the full text. In addition, no limitation on the period of publication was used.
After the search process in the databases, the filtering process proposed by the SSF method was performed. The documents found were managed with the aid of bibliography management software.

4. THE LEAN STARTUP APPROACH APPLIED TO THE DEVELOPMENT OF MANUFACTURED PRODUCTS

After the realization of the bibliography search, a total of 121 articles were collected from the four databases used in the search. Initially, duplicate documents were eliminated, leaving a total of 69 articles, which were later systematically analyzed. These articles went through a filtering process based on the reading of the title, abstract, and keywords, being possible to identify 21 articles that were possibly aligned with the research theme. Of these, 16 available articles were identified. A summary of the findings of the literature review by databases is presented in Table 1.

Table 1. Findings of the systematic literature review and the results after the analysis by SSF method.

String (("lean startup" OR "build-measure-learn" OR "feedback cycle" OR "hypothesis creation" OR "hypothesis elaboration") AND ("product development" OR "design process" OR "product design" OR "physical product*" OR "manufactur*" OR hardware) AND NOT "software")	
Search date: 09/21/2020	
Data Bases	**Number of Articles**
Engineering Village	25
Ebsco	7
Scopus	54
Web of Science	35
Total	121
Analysis	**Remaining Articles**
After eliminating duplicate articles	69
After filtering (Title/Abstract/Keywords)	21
Filtered articles available for reading	16

Analyzing the years of publication of the selected studies (Figure 3) after the filtering process it is possible to see that the topic has recently become an object of study, and no studies before 2012 were found. It is also observed that this field of study has been growing over the years - the small number of studies referring to the year 2020 is possibly related to the date of the research.

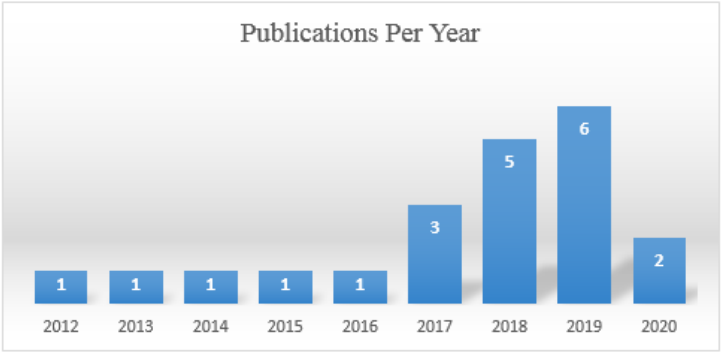

Figure 3. Graph for analysis of years of publication of studies found in the literature review after filtering by title, abstract, and keywords.

After the filtering process, an analysis was performed using the VOSViewer program, to assess the main keywords mentioned in the studies found. Figure 4 shows the network formed from the analysis of the keywords cited at least twice in the found studies. From this analysis, it was possible to see that the words "lean startup" form a strong link with the word "innovation", which demonstrates the use of the lean startup approach as a way to promote or assist in the search for innovation. Among other observations, it was also noted that words related to manufactured products were no longer used as keywords, which may lead to the interpretation that this area of research is still poorly explored.

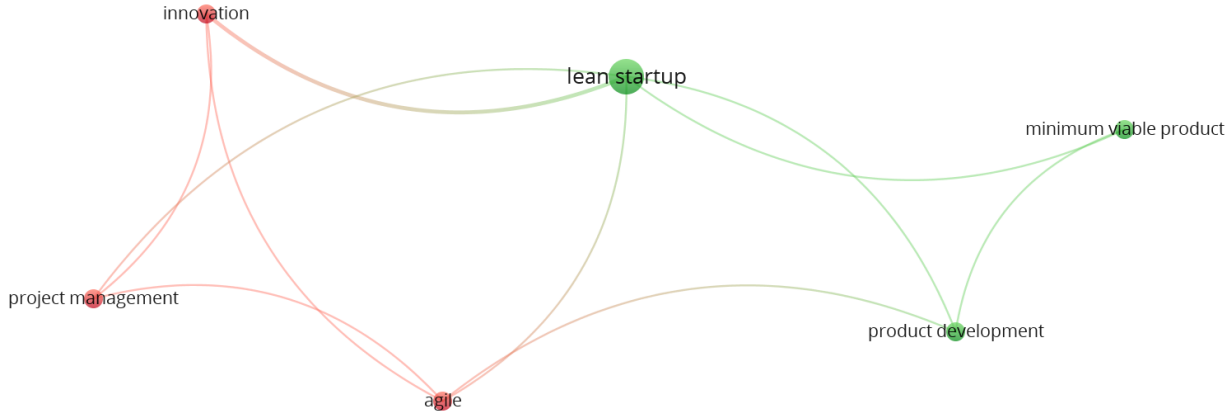

Figure 4. The network built in the bibliometric analysis software VOSViewer related to the keywords cited at least twice among the available studies filtered at the end of the analysis with the SSF method.

Among the 16 articles selected available for reading, only 4 of them dealt in any way with the use of the Lean Startup approach or its practices in the development of manufactured products. The selected articles were analyzed in detail and, based on this, Table 2 was created, in which the main aspects related to each article are described, as well as are made individual observations for each one.

Table 2. Articles analyzed in the systematic search phase on the use of the Lean Startup approach in the development of manufactured products.

Article Description	Analysis
Authors: L. W. M. Wienhofen, C. Lindkvist and M. Noebels **Year of publication:** 2014 **Title:** User-centered design for smart solar-powered micro-grid communities	It uses user-focused tools in conjunction with practices from the Lean Startup approach (more specifically the build-measure-learn iterative cycle) in a project called CoSSMic (Smart Solar Collaboration Microgrids). A series of iterative cycles were carried out with users, allowing them to give early feedback on what they would like about CoSSMic's technology and software. From these feedbacks, the project conceptions were elaborated. According to the authors, the iteration practices enabled a lot of success in building relationships between potential users and project teams, as well as started a kind of forum in which potential users of the product could present their comments on what is being developed.

	As the article discusses using a variety of tools in addition to the Lean Startup approach, no details are given on how to manage the build-measure-learn cycles and product development. The hypotheses tested in each cycle or how they were developed are also not reported. Furthermore, the authors do not present how the results obtained from the use of these tools and approaches were measured. Some points that can be perceived as difficulties refer to how interactions between different users are performed - in the work in question, the experiments were applied at the same time with different groups, and the feedbacks generated were often the result of the influence of a group about each other. Still, it is also important to highlight that during the execution of the different cycles of experiments, some users gave up participating in the interactions, which can also be perceived as possible difficulty in applying the approach.
Authors: R. Hostettler, A. I. Bohmer, U. Lindemann and A. Knoll **Year of publication:** 2017 **Title:** TAF agile framework: Reducing uncertainty within minimum time and resources	Arguing that in the uncertain context in which companies are currently inserted, traditional product development methods have limited effectiveness, and that the companies often do not have the speed of adaptation and implementation necessary to face this challenge, there is a need for a structure of consistent, easy-to-implement agile development. Thus, the authors developed an agile framework, based on Lean Startup, Design Thinking, and traditional product development, managed by PDCA cycles. The framework in question was applied with students, in an environment characterized as a laboratory. From its use, greater development of the team was observed, according to the authors' perception, and also the execution of more detailed projects, and in the cycle of using the framework, the teams delivered 35% more critical functions of the product when compared to others experiences without using the framework. Still, from interviews with the participants, it was confirmed that they evaluated the framework as useful and would use it in the future. Despite dealing with physical product development, the use of Startup Lean practices continues to focus on business development and not on the product itself. Furthermore, it is not specifically addressed which practices related to the Lean Startup approach were used. Still, the framework was only applied in a laboratory environment, which may not portray the reality of a real industrial environment. Regarding the type of product designed, was worked only with the development of simple products, not highlighting the possible differences and difficulties faced when using the framework for the development of more complex products. Regarding the respondents' perception of the usefulness of the framework, it is important to highlight that the positive percentage found was 46%, which shows that more than half of the participants may have encountered some difficulty with its use or just did not perceive the framework as useful. No greater emphasis is given to this factor and its possible implications. Two points of greatest difficulty were found with the use of the proposed framework and which are linked to the practices of the Startup Lean approach. The first difficulty is related to the objective of using the interaction cycles: it was noticed that the teams could not use the feedback obtained from the execution of the interaction cycles as a way to obtain learning - what happened was that they used the feedbacks only for enhance your final product idea. The second perceived difficulty is related to the construction of MVPs: the teams were resistant to develop partial products to be used in experiments, which can hinder the execution of development cycles.
Authors: W. S. Dewobroto and I. A. Marie **Year of publication:** 2020 **Title:** Lean Startup Approach on Product Design and Manufacture Facility Planning in Uncertain Business Climate	Have as an objective to present the conception of the Lean Startup approach and its application in the design of physical products. The authors compare the approach in question with a generic method traditionally used in the development of manufactured products. After the theoretical comparison was carried out, the authors argue that the Lean Startup approach is suitable for this purpose, since the validation process at each stage of the product development process will increase the possibility of the resulting products meeting consumer desires and will reduce the time needed to launch it. Still, according to the authors, for a company to be successful and be able to control uncertainties, a flexible, fast, and valid product development process is necessary, and the Lean Startup approach is appropriate for this. The article in question addresses only a theoretical presentation of concepts related to the Lean Startup approach, not demonstrating how it can be used in the

	practice to develop physical products. When it comes to the manufacturing sector more specifically, the focus is only on the use of manufacturing cells and group technologies. No possible difficulties are reported or perceived with the use of the approach.
Authors: E. Sonta-Draczkowska and M. Mrozewski **Year of publication:** 2020 **Title:** Exploring the Role of Project Management in Product Development of New Technology-Based Firms	It seeks to answer two research questions: (a) What project management practices do new technology-based companies apply in the process of developing new products, and how do entrepreneurs perceive their role in the success of the enterprise? (b) What contingencies can determine the selection of project management practices for the development of new products in the context of new technology-based companies? To answer the research questions, the authors carried out a literature review, followed by a focus group workshop (to identify the areas that should be investigated in the study). After that, semi-structured interviews were carried out. Among one of the practices used, the Lean Startup approach stood out, focusing mainly on the use of MVPs, client development, and pivoting. Regarding contingencies, the authors highlighted that companies that develop hardware-based products apply more physical artifacts, for example, prototyping. Still, they also highlight that the study in question can be interesting for corporate managers who seek to improve research and development processes, applying Lean and agile practices to increase flexibility and orientation for the current market of product development. It does not focus on the use of the Lean Startup approach in hardware companies, however, a small range of the sample represented companies focused on the development of physical products. Furthermore, the authors treat Lean Startup separately from agile methodologies and do not develop the "how" this approach can be used and managed in practice. Even so, it is possible to identify some difficulties in using the practices of the Lean Startup approach. One of them is related to the measurement and learning phases: often what customers want is different from what they need, and still, many cannot correctly express any of these things, which makes it necessary for the project team to have sensibility and attention during the execution of the cycles and in the validation of the learning obtained. Another perceived difficulty is related to the limitation generated by different cultures and types of companies – this factor needs to be considered when making use of practices, and it is possible to adapt them to different situations.

From the analysis of the articles, it was possible to notice that the use of the Lean Startup approach or its practices in the development of manufactured products can still be considered an unexplored field, with many possibilities to be investigated.

Among the articles analyzed, only two examine the use of the approach in a practical way, one of which was carried out in a laboratory environment, outside the business context. It was also observed that the Lean Startup approach is not applied isolated, but in conjunction with other management and development practices, as can be seen in the articles by Hostettler *et al.* (2017) and Wienhofen *et al.* (2014). This hybrid way of working is supported by Cooper (2016), since, according to the author, the single application of agile methods is not enough to support the development of manufactured products, since in this context the challenges faced are very different from those involved in the field of information technology or software development.

Another issue to be highlighted is that, although these studies cite the use of the practices of the Lean Startup approach, how they are managed and the challenges faced in this management are not portrayed. Still, even if the possibility of using lean and agile practices in the development of products by large corporations is mentioned (Sonta-Draczkowska and Mrozewski, 2020) or in the development of physical products (Dewobroto and Marie, 2020), today it is not presented how to do this.

Analyzing the articles, it was also possible to observe some possible difficulties with the use of the Lean Startup approach in the context of manufactured products.

It was noticed in the studies of Wienhofen *et al.* (2014), Hostettler *et al.* (2017), and Sonta-Draczkowska and Mrozewski (2020), that a point of difficulty is related to customer and user feedback, with the main obstacle being the step of evaluating the veracity of the obtained feedback. It is noted that there is some difficulty in knowing how to observe and capture the feedback, and often the very form of application and management of the experiment can influence the feedback provided, making it easier for it to become biased or limited.

Another perceived difficulty point is related to how the feedbacks obtained are used and with the development of the product itself. It was observed in the study by Hostettler *et al.* (2017) that the project teams had some resistance in making use of customer or user feedback to build the product, using it only to modify their idea of the final product - and could

even postpone or deny a possible necessary pivoting decision. Thus, it is clear that the concept of learning within the approach of Lean Startup also requires a cultural and behavioral change of those involved.

Also, the correct definition of who will be the customers or users who will be part of the execution of the experiments was perceived as a difficulty. The fact that there is withdrawal at a certain point in the development by some users in the study by Wienhofen *et al.* (2014) may have influenced the final result of the product, so it is highlighted that the project team needs to be attentive to customers or users who will be part of the experiments. Is necessary to seek to select only those who truly demonstrate commitment and interest in what is being developed.

Another topic observed is related to the use of MVPs to experiment with customers or users. Show to the customer a partial product, that is, one that does not yet contain all the idealized functionalities or an imperfect product goes against the traditionally used logic – presenting the product to the customer only when it is finished. Thus, this factor is also shown as a difficulty involved in using the Lean Startup approach for the development of manufactured products.

Still, another factor that can hinder the use of the approach refers to the apprehension of sharing information in advance with external customers. Often, the project team may feel insecure during the execution of experiments with people outside the company, for fear of having their ideas exposed to competitors or even of an experiment not accepted by customers affect the company's moral impact. According to Ries (2012), regarding this factor, it is necessary that the team considers the possible risks and their solutions (for example, the creation of a patent for an innovative idea), but that they focus their efforts on learning faster than its competitors.

Finally, a positive point observed from the analysis of the articles confirms the need to improve traditional product development methodologies so that they can adapt to the current market, characterized by high volatility (Hostettler *et al.*, 2017). Thus, the combination of these traditional methodologies and tools aimed at agile proves to be promising and useful.

5. CONCLUSION

In the present work, was sought to analyze the scientific production about the use of the Lean Startup approach in the development of manufactured products, and from this to propose new directions to expand the frontier of knowledge. Although a significant number of articles related to the topic were found, none of them dealt specifically with the use of the Lean Startup approach or its practices in the process of developing manufactured products. The result was not different from what was expected, because, although the literature suggests the possibility of this approach being implemented for the development of physical products, the Lean Startup approach and its practices can be considered quite new. Thus, its application in environments different from software startups is even newer, having recently become the object of research studies.

Traditionally, the project team's relationship with customers happens only at specific points during development, and not in an ongoing way. This method of working can lead to rework or even failure of the product in the market, due to problems in identifying the wishes and needs of customers, which are not continuously validated – characterizing a development in long cycles. Using the Lean Startup approach, the project team's relationship with customers is strengthened through frequent interactions throughout product development, based on working in short cycles. This form of development allows the team to notice possible errors in advance and can act to correct and test new hypotheses more quickly, reducing uncertainties and rework, in addition to favoring the development of a value-centric product from the point of view of customers and users. Thus, the Lean Startup approach is perceived as a way to improve product development.

More specifically, in the study developed by Wienhofen *et al.* (2014), it was noticed that it is possible to make use of parts of the lean startup method in conjunction with other tools and product development practices, such as the BML cycle and storyboards. This union between practices enabled a greater development of relationships with the different users of the product and also the possibility of initial feedback on how these users see the project and what they would like about the technology and software developed.

Likewise, the work developed by Hostettler *et al.* (2017), also demonstrates the possibility of uniting parts of the Lean Startup approach with other more traditional product development practices. However, it is noteworthy that the study in question does not focus on the development of the methodology itself and how it was applied in detail. Despite this and other limitations of the work, positive results are reported, and from the use of the TAF framework developed by the authors, all groups of designers were able to deliver a complete prototype of the product - which did not happen without the use of the framework.

The studies by Dewobroto and Marie (2020) and Sonta-Draczkowska and Mrozewski (2020) did not effectively demonstrate the use of the Startup Lean approach or any of its practices in product development, however, they provide indications that the approach can promote improvements in the PDP of physical products. It is also observed that the Startup Lean approach is already present in different companies as a way to accelerate and anticipate the process of obtaining feedback on the developed product, making this process more flexible.

In general, it was observed that the main difficulties involved in using the Lean Startup approach for the development of manufactured products are related to behavioral and mentality changes. It is noteworthy that these changes do not only occur within the project team itself but must also occur at other organizational levels of the company, that is, everyone

must be aligned to the same objective and understand the proposed way of working. However, when analyzing the bibliography, specific points of difficulty that require greater attention were identified, which may be the object of future studies on the subject.

Regarding interactions, the project team must plan and be attentive as to how the interaction with the client or user will be made and conducted. Poorly planned and executed interactions can generate limited or even partial feedbacks, for example, in a focus group interaction is possible for one group or person to stand out or influence another, which can affect the veracity of the feedback provided. Thus, research aimed at planning the experiment may be useful, seeking to highlight aspects such as the construction of the experiment itself - how it will be applied and managed during interactions with the real client. It is also suggested that the metrics used in the experiments be specifically analyzed: how to define and manage them in the context of manufactured products so that it is possible to establish the relationship between the result of the experiment and the hypothesis being tested.

Still on the construction of the experiments, the team needs to be aware of the type of experiment they are building and, in addition, have a clear understanding of the purpose of using the Lean Startup approach. It is possible that during the elaboration of the experiment, the project team finds it difficult to carry out the experimentation using a partial product or only with minimal functionalities. Traditionally, the forms of validating a product with a customer occur only after it has been fully developed, which differs from the form of validation used in Lean Startup. In the approach in question, the idea is to validate hypotheses about the product's features, working in short cycles, building it from the feedbacks generated at each execution of the cycle. Thus, it is proposed to carry out more studies focused on the execution of short cycles within the context of manufactured products, such as how product development occurs, what are the main difficulties observed in practice, what behavioral changes are necessary for members of the project team and how they happen or can be stimulated.

Customers often have difficulty in expressing their desires and needs clearly and objectively, so the project team must know how to identify what they want, and still differentiate this from what they need. This requires from the project team a careful look, observing the customers' reaction to the applied experiment, not just a simple opinion. It is also necessary for the team to identify who their true customers are and know how to benefit from the feedback generated from the experiments, that is, use them to learn about the customer and to develop and evaluate the best solution, not just to enhance your idea of the final product. Thus, studies focused on the themes of defining the customers who will be part of the experiments, the construction of partial products (or MVPs) for experimentation with customers, and also the learning phase after the experiment is carried out are suggested.

Also, in the learning phase, it is necessary that the project team, and even the company's management, be prepared to deal with the feedbacks obtained, leaving aside their ideas of success or preconceived solutions, taking into account the positions of customers and users. This factor can also be seen from the point of view of personal development, as those involved in the product project must know how to deal with the fact that they often will have their opinions, ideas and hypotheses refuted at the end of an experiment. Research addressing the processes involved in this phase is also suggested.

In addition to the points noted above, other possible themes for future studies can be mentioned, such as the use of the Lean Startup approach with a focus on internal customers, the creation of hypotheses to be tested, the type of planning used to work with short-cycle approaches, and the management of the pivoting process. Other themes also are the form of organization and behavior of the company as a whole when using development based on testable hypotheses and the new form of leadership required when working with the approach in question.

Finally, it is possible to see that this can be considered a trending theme within the PDP, and it is also clear that the use of the Lean Startup approach in the context of the development of manufactured products, although it can be considered a still unexplored field, is already capable of bringing real benefits to industries that seek to improve their way of product development, proving to be a very promising research object.

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7. RESPONSIBILITY NOTICE

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