

Managing Uncertainties during the Development Process of Technological Innovation Projects: Lean Startup Contributions

June Marques Fernandes, Luciana Paula Reis and Thiago Geraldo dos Santos

Universidade Federal de Ouro Preto (UFOP), João Monlevade, Brazil

june@ufop.edu.br

lucianapaula@ufop.edu.br

thiago.geraldo@aluno.ufop.edu.br

Abstract: During the development of technological innovation projects, the team has difficulty to identify and managing uncertainties, which represents a challenge to bring the technologies closer to the market. Although there are studies on the management of uncertainties in innovation projects in different contexts of organizations, no studies were found relating to the adoption of Lean Startup (LS) practices and the management of uncertainties during the development of technological project processes in academic environments. Thus, this research aims to identify the uncertainties that can be mitigated during the development of these technological projects using LS practices. A multiple case study was conducted within a Brazilian federal university to fill this gap, analyzing nine technological innovation projects. The research consisted of identifying the uncertainties experienced by the project innovation development team before and after the application of LS practices. In the end, the uncertainties were analyzed in the context of each technological project, considering the mitigation achieved after applying the LS practices, and comparing them with their initial state. As a result, it was observed that the initial uncertainty categories most experienced by the project teams were related to products and resources, especially those related to knowledge and team profile. When evaluating the uncertainties after applying the LS practices, it was possible to observe that the most mitigated uncertainties were related to resources followed by the business model, the latter being the third most experienced in the initial scenario of the project development process. On the other hand, the uncertainties related to products were the ones that presented the least mitigation. Regarding resource uncertainties, the LS practices contributed to the mitigation, specifically those related to process quality, obtaining resources and knowledge, and team profile. As for the uncertainties observed in the business model, better results were observed specifically in those focused on marketing strategy, pilot production, and definition of the revenue model. It is concluded that the LS practices made more significant contributions to the business-related uncertainties than to product-related ones since product-related uncertainties were the ones that obtained the lowest mitigation results.

Keywords: Lean Startup Practices. Uncertainty. Technological Innovation Projects. Projects.

1. Introduction

Risk and uncertainty are interrelated concepts with an inevitable interdependence. Risk is the effect that, when it occurs, has negative consequences (Sicotte and Bourgault, 2008). On the other hand, uncertainty is characterized by events that cannot be associated with the probabilities of their results (Gomes *et al.*, 2020). Uncertainties are often explained by two main causes: internal (related to the behavior of actors) and external (technological changes, market changes, for example) (Gomes *et al.*, 2020). Uncertainty management is an important factor in the formulation and implementation of nascent business strategies (Fernandes, Reis, Sérgio, 2017) and represents a major challenge for economies in constant innovation. In the academic environment, these unmanaged uncertainties can have a negative impact on the development process of technological innovation projects, which can lead to the failure of these innovations (Fernandes, Reis, Sérgio, 2017).

During the process of technological innovation, different types of uncertainties occur, such as technological and market uncertainties (Huang *et al.*, 2022; Sicotte and Bourgault, 2008). Uncertainties generate waste, such as waiting time, unnecessary circulation of documents (Araujo *et al.*, 2023), and the development of bad prototypes. The management of these uncertainties thus contributes to formulating and implementing technological business strategies (Fernandes, Reis, Sérgio, 2017), and also in preparing to reduce barriers to the adoption of new principles and technologies such as those related to Industry 4.0 (Cordeiro *et al.*, 2023a; Cordeiro *et al.*, 2023b; Carvalho de Sá *et al.*, 2022).

In this context, we discuss Lean Startup (LS) practices, which represent a set of tools to guide data collection and organization of information about products and markets, to mitigate different wastes (Ghezzi and Cavallo, 2020). These practices allow the improvement of the flow of information between those involved in the project (Reis *et al.*, 2022; Reis *et al.*, 2021; Reis, Fernandes, Armellini, 2021; Gomes *et al.*, 2020) and, consequently, promote the reduction of uncertainties inherent in the development process (Fernandes, Reis, Sérgio, 2017) since they can speed up the decision-making process (Zorzetti *et al.*, 2022; Ries, 2011).

In the researched literature, no studies were found to identify and evaluate in which situations LS practices

can contribute to the management and reduction of uncertainties during the development process of technological innovation projects. Thus, the objective of this investigation is to identify the uncertainties that can be mitigated during the development of these technological projects using LS practices. To do so, we consider five LS practices: i) Business Model Canvas; ii) Validation Board; iii) Minimum Viable Product ; iv) Empathy Map, and v) Value Proposition Canvas.

2. Theory Background

2.1 Innovations in the academic environment and LS practices

Technological innovation is related to significant improvements or new developments of products, services, or processes that are capable of generating additional value for the business or for customers (Reis *et al.*, 2022; Araújo, Reis, Morais, 2021; Reis *et al.*, 2018). This process of technological, both those conducted by large companies and those from the academic environment, are essential for the social and economic development of a country (Caviggioli *et al.*, 2023; Reis *et al.*, 2022).

Universities, as organizations capable of producing, disseminating, and applying knowledge, are considered essential to promote the process of technological innovation (Caviggioli *et al.*, 2023, Silva *et al.*, 2019) since they produce technologies that impact the generation of wealth and social development (Reis *et al.*, 2022; Boguszewicz-Kreft *et al.*, 2021).

Despite the importance of these technological innovations, development teams face several difficulties in making their projects develop and thrive, since, they are embedded in uncertain and volatile environments. These uncertainties lead teams to perform their activities using a trial-and-error approach, without the correct sequencing of activities necessary for project consolidation (Miller *et al.*, 2020).

These difficulties caused by volatility and uncertainty demonstrate the importance of developing methodologies and tools capable of managing such uncertainties and thus contributing to the process of formulating and implementing strategies technological business strategies that help operationalize the process of technological innovation (Jesemann *et al.*, 2021; Reis *et al.*, 2021; Fernandes, Reis, Sérgio, 2017). Within this context, LS brings a set of practices capable of assisting the process of implementing business technology strategies and, consequently, supporting the process of technological innovation (Fernandes, Reis, Sérgio, 2017).

LS is a methodology that aims to understand and assist the development of new innovative businesses immersed in a set of uncertainties and high-risk environments in a lean way (Reis *et al.*, 2023; Reis, Fernandes, Armellini, 2021; Veiga, 2015). It comprises a set of practices that seek to make the development process more dynamic, fast, and reliable, through continuous testing of product and business validation using an approach based on learning and information exchange (Jesemann *et al.*, 2021).

The LS practices explained in Figure 1 contribute to technology, product, and business development (De Faria, Santos, Zaidan, 2021; Ghezzi and Cavallo, 2020), as they enable the identification of customers and competitors and identify ways of relating to the market to generate value for the product or service and check market trends (Jesemann *et al.*, 2021; Dewobroto and Marie, 2020).

PRACTICE	CONCEPT	AUTHORS
Business Model Canvas (BMC)	It consists of a visual map of the company, divided into nine elements that help structure the business model, logically describing how the company intends to create, deliver and capture value.	Hidayat, Hendrix, Hidayat (2018); Pitayachaval, Chittrakool, Arjharn (2017) Osterwalder and Pigneur (2011)
Validation Board (VB)	It is a tool used to validate business-related problems, which helps teams to plan, execute and evaluate in a structured way the suitability of solutions for customers.	Peralta <i>et al.</i> (2020); Ardyanti <i>et al.</i> (2019); Veiga (2015)
Minimum Viable Product (MVP)	First prototype created with the lowest possible investment, capable of quickly demonstrating the value of the product to the customer and verifying whether the business is able (or not) to enter the market.	Jesemann <i>et al.</i> (2021); Maludin <i>et al.</i> (2021); Hokkanen, Kuusinen and Väinänen (2016)
Empathy Map (EM)	It is a tool used to capture customer information and needs in order to develop new solutions to old issues or rediscover old solutions to new issues.	Kahan <i>et al.</i> (2021); Staniec and Pilawa (2020); Osterwalder and Pigneur (2011)
Value Proposition Canvas (VPC)	It helps to better understand the customer and define a unique and attractive value proposition that is capable of promoting differentiation from competitors, in addition to structuring the way in which the product or service relates to customer needs.	Puurttinen and Pohjola (2021); Päivi and Helena (2020); Veiga (2015)

Figure 1: LS practices concepts

Source: The authors.

It can be observed that these practices focus on i) structuring the value proposition and customer segmentation (De Faria, Santos, Zaidan, 2021; Dewobroto and Marie, 2020), ii) encouraging interaction and information exchange among project members so that there is improvement in the organizational learning process (Reis, Fernandes, Armellini, 2021; Mansoori, Karlsson, Lundqvist, 2019) iii) so that the team can reduce resource utilization, minimize waste, and effectively address risks, uncertainties, and opportunities while generating value for the customer (Reis *et al.*, 2022).

2.2 Uncertainty and technological innovation

Technological projects inserted in the academic context are subject to internal and external actions that influence their performance and continuity (Miller *et al.*, 2020; Fernandes, Reis, Sério, 2017). During the process of technological innovation, there are uncertainties (Miller *et al.*, 2020) that must be managed to define operational actions, priorities, and objectives capable of delivering superior performance (Eker and Eker, 2019). Uncertainties related to the external environment, for example, make it difficult for companies to formulate and implement strategies, in addition to impacting decision-making (Reis *et al.*, 2022; Janka and Guenther, 2018).

Seminal studies address different categories of uncertainties, uncertainties related to the customer, technology, competition, and resources, among others (Jaworski and Kohli, 1993; Milliken, 1987; Jauch and Kraft, 1986). From the literature, seven categories of uncertainty were identified. Figure 2 presents these uncertainty categories.

Studies show how uncertainties can affect business activities, product, and service development project performance (Gomes *et al.*, 2020), both in the development process and in the project organization (Lee and Xu, 2019; Janka and Guenther, 2018). The literature shows that the need to manage uncertainty is more evident within new and small firms, as they tend to face greater business uncertainty than large firms (Elias *et al.*, 2022; Reis *et al.*, 2022), but despite this, they prefer to adopt improvisation in a short time rather than focusing on providing the necessary resources (Huang *et al.*, 2022).

Customer uncertainty and technology uncertainty are inherent to the process of technological innovation due to their environment and are addressed by Ye and Mai (2018) as uncertainties of the environment. Given this scenario, startups need to find ways to better deal with uncertainty to take advantage of market opportunities and capture new customers (Felin *et al.*, 2020; Foss, Klein, Bjørnskov, 2019), in addition to needing to be aware of the innovations that appear in the market (Ghezzi and Cavallo, 2020).

Categories	Description	Authors
Customer uncertainty (external environment uncertainty)	Uncertainty related to information coming from the market, including segment identification, changes in customer requirements, identification of distribution channels for products and services.	Huang <i>et al.</i> , 2022; Felin <i>et al.</i> , 2020; Foss, Klein, Bjørnskov, 2019; Ye and Mai, 2018
Technology uncertainty	Technological uncertainties talk about the main technological elements, the operation of technology, intellectual property, legalization, and registration of products.	Huang <i>et al.</i> , 2022; Ghezzi e Cavallo, 2020; Ye and Mai, 2018; Arteaga and Hyland, 2013
Competitive uncertainty (competitors)	Competitive uncertainty involves all changes in the competitive landscape, including competitors' actions and performance.	Jaworski and Kohli, 1993; Milliken, 1987; Jauch and Kraft, 1986
Resource uncertainty (internal uncertainty)	Related to the availability of and access to any additional specialized human or technical resources, goods or tools required for the process.	Xiong, Yang, Jia, 2019; Ye and Mai, 2018; Arteaga and Hyland, 2013; Vera and Crossan, 2005; Cunha, Cunha, Kamoche, 2003
Product uncertainty	Uncertainties related to product design and value proposition.	Felin <i>et al.</i> , 2020; Ghezzi e Cavallo, 2020, Mansoori, Karlsson, Lundqvist, 2019
Partnerships uncertainty (customer integration and financial partners)	It involves the entire relationship with partners in the co-innovation process, as well as partners in external funding sources, investors' risk perception, and purchase channels.	Arteaga and Hyland, 2013; Song, Ming, Xu, 2013; Enkel, Kausch, Gassman, 2005
Business model uncertainty	How to define trading strategies, a model for making a profit, and prices.	Felin <i>et al.</i> , 2020; Ghezzi e Cavallo, 2020, Mansoori, Karlsson, Lundqvist, 2019

Figure 2: Uncertainty Categories

Source: Based on literature review.

To respond to constant environmental changes, it is necessary to mitigate resource-related uncertainties by allocating existing resources optimally and effectively (Ye and Mai, 2018; Cunha, Cunha, Kamoche, 2003).

Xiong, Yang, and Jia (2019), highlight the need to seek new resources while making efficient use of available resources. Vera and Crossan (2005) emphasize not only the acquisition of new resources but also innovation.

Due to the volatility and speed of the market in which they are inserted, these startups have difficulties assembling a minimum viable product and validating their business model, where many times they are not tested against the market, generating an unwanted scenario of uncertainty (Felin *et al.*, 2020; Mansoori, Karlsson, Lundqvist, 2019). Other studies point out that these scenarios provide faster learning for the team, which contributes to uncertainty mitigation (Prashantham and Floyd, 2019; Xiong, Yang, Jia, 2019).

3. Methodology

The methodological approach used in this paper was a case study, for being a methodology that allows understanding the real world and acquiring knowledge to conclusions (Yin, 2008). As units of analysis, nine technological innovation projects were selected and developed within a Brazilian federal university. These projects (Figure 3) participated in the IIP program that aims to foster innovation in academics. They are selected by the university committee and by government institutions.

Projects	Knowledge	Application
Case 1	Pharmaceuticals	Male infertility in case of low count and / or motility of sperm.
Case 2	Mechanical and organic chemistry	Manufacture of organic electronic devices, conductive tracks, resistors, capacitors, and inductors plans, and then diodes, transistors and OLEDs.
Case 3	Mobile and cloud computing	Document management and cloud storage.
Case 4	Applied Mechanics	Detection of fractures in sleepers made of steel.
Case 5	Computer and Cytology	External quality monitoring for cytopathology of tipoll.
Case 6	Food and Chemical	Quality Monitoring and deterioration of real-time meat.
Case 7	Clean Energy	Economic and sustainable energy generation.
Case 8	Food and Chemical	Intelligent packaging with natural preservatives.
Case 9	Blockbuster Games - Technology and Innovation	Social inclusion of visually impaired people through assistive technology in the gaming market.

Figure 3: Characterization of the studied projects

Source: The authors.

The research consisted of identifying the uncertainties experienced by the project's innovation development team before and after applying the LS practices. During a period of 12 months, the five LS practices mentioned in the literature were applied simultaneously in the 9 cases (see Figure 1). For each practice, templates were created to guide its application. The practices were applied in parallel in such a way that the information collected in one was used in the application and the templates were always refined according to technological development. After this period, in which all practices had been applied to all cases, the final situation was analyzed. In the end, the uncertainties were analyzed in the context of each technological project, considering the mitigation achieved after applying the LS practices, and comparing them with their initial state.

For conducting data collection, several sources of evidence were involved in the case study (Yin, 2008), such as online meetings, semi-structured interviews, questionnaires, document consultation, and direct observation, which allowed follow the implementation of LS practices during a period of six months. Spreadsheets containing the standard theoretical framework of LS practices served as a template for the project teams during implementation. Two representatives from each project were interviewed, based on 11 questions and this data collection allowed for a strong connection with empirical reality, providing validation of the theory.

Through the analysis of the information collected by the different sources of evidence used, it was possible to triangulate the data (Yin, 2008). As a result, it was observed that the uncertainty categories most initially experienced by project teams were related to products and resources, especially those related to team knowledge and profile.

4. Data Presentation

The interviews with those involved in the projects were transcribed and coded about the problems faced by the teams during the technological innovation process, being related to a category and subcategory of uncertainty present in the literature. The relationships established allowed a more detailed assessment of the impact of adopting LS practices simultaneously on the types of uncertainties experienced. Each project had

internal standards that ended up being common to other projects, thus allowing the assessment of similarities and differences between the impacts of adopting combined LS practices to mitigate the uncertainties experienced. The segmentation into categories and subcategories, as well as the number of uncertainties initially experienced by the projects, are shown in Figure 4.

Uncertainty category	Uncertainty subcategories	C1	C2	C3	C4	C5	C6	C7	C8	C9	Total/Percent	
Customer uncertainty	Market segment		1	1	1	1	1	1	1	1	8	13.56%
	Distribution channel									1	1	1.69%
Technology uncertainty	Technological protection	1	1	1				1	1		5	8.47%
Resource uncertainty	Process Quality	1							1		2	3.39%
	Knowledge and team profile		2	2	1		1	1		3	10	16.95%
	Resource obtainment				1	1			1		3	5.08%
Product uncertainty	Product Design. Product Value Attribute	1	1	1	1		1	2			7	11.86%
	Market application	1	1	1	1	1		1		1	7	11.86%
	Portfolio prioritization									1	1	1.69%
Partnerships uncertainty	Supplier	1									1	1.69%
	Relationship with the consumer		1								1	1.69%
Business model uncertainty	Revenue Template		1	1	1			1		1	5	8.47%
	Marketing strategy			1			1	1	1	3	7	11.86%
	Pilot production						1				1	1.69%
		5	8	8	6	3	5	8	5	11	59	100.00%

Figure 4: Frequency of uncertainties that are experienced by the different projects analyzed

Source: The authors.

Analyzing Figure 4, we have:

- a) Initially, a total of 59 uncertainties experienced by different projects were raised, and it is important to highlight that a project can experience more than one category of uncertainty.
- b) The categories "resource uncertainty" (25.42%), "product uncertainty" (25.42%), and "business model uncertainty" (22.03%) are the three categories that presented the highest frequency of occurrence among the projects.
- c) Analyzing the subcategory level, those with the highest frequency of occurrence are "knowledge and team profile" (16.95%) and "market segment" (13.56%), the first being linked to the category of "resource uncertainty" and the latter linked to the category of "customer uncertainty" category. Soon after, with 11.86%, the subcategories of "product design, product value attribute", "market application" and "market strategy" appear.

After analyzing the initial uncertainties, the five LS practices mentioned at the beginning of this paper were applied. At the end of the application, the development team identified and validated those that were possible to be worked through practices. Thus, to better understand the possible contributions of LS practices in mitigating uncertainties, a comparative table was prepared between initial uncertainties, resolved uncertainties, and unresolved uncertainties, applying the same categorization used during the initial survey, as shown in Figure 5. Furthermore, to enable a more assertive analysis of the contribution of LS practices to the mitigation of uncertainties, an indicator called mitigation level was created (for the categories and subcategories), which demonstrates the degree of resolution of uncertainties compared to initial uncertainties. This indicator is calculated by the existing ratio between the number of uncertainties experienced by the projects after the application of the practices by the number of initial uncertainties identified in the projects. The uncertainties mitigated over the course of technological development were the result of the combined use of practices. It should be noted that as the practices were applied simultaneously, it was not possible to identify individual contributions to the mitigation of waste.

Analyzing Figure 5, it is observed that:

- a) The "resource uncertainty" category was the one that presented the best results from the adoption of LS practices, with a 60% uncertainty mitigation level, indicating that projects were able to resolve 60% of the initial uncertainties experienced.
- b) The "partnerships uncertainty" category that had the lowest number of uncertainties initially, after adopting LS practices was the second with the highest mitigation level (50%), indicating that this level is not directly

related to the number of initial uncertainty experienced.

c) The "product uncertainty" category that appeared in the initial scenario as the first in several uncertainties along with the "resource uncertainty" category, after applying the practices, was the category that presented the lowest level of mitigation (20%), which corroborates the indication that a greater amount of initial uncertainties is not related to a higher level of mitigation.

To carry out the analysis of the results at the level of subcategories, those that presented uncertainties that appeared only once in one of the cases were excluded since this would only allow a dichotomous analysis between 0% and 100%. Thus, distribution channel, portfolio prioritization, supplier, relationship with the consumer, and pilot production were removed from our analysis, and subcategories represent only 1.69% of the initial uncertainties.

Uncertainty categories	Uncertainty subcategories	Initial Uncertainty		Resolved Uncertainty		Unresolved Uncertainty		Mitigation level (categories)	Mitigation level (subcategories)
		Count	Percentage	Count	Percentage	Count	Percentage		
Customer uncertainty	Market segment	8	13.56%	2	3.39%	6	10.17%	22.22%	25.00%
	Distribution channel	1	1.69%	0	0.00%	1	1.69%		0.00%
Technology uncertainty	Technological protection	5	8.47%	2	3.39%	3	5.08%	40.00%	40.00%
Resource uncertainty	Process Quality	2	3.39%	2	3.39%	0	0.00%	60.00%	100.00%
	Knowledge and team profile	10	16.95%	6	10.17%	4	6.78%		60.00%
	Resource obtainment	3	5.08%	1	1.69%	2	3.39%		33.33%
Product uncertainty	Product Design. Product Value Attribute	7	11.86%	1	1.69%	6	10.17%	20.00%	14.29%
	Market application	7	11.86%	2	3.39%	5	8.47%		28.57%
	Portfolio prioritization	1	1.69%	0	0.00%	1	1.69%		0.00%
Partnerships uncertainty	Supplier	1	1.69%	0	0.00%	1	1.69%	50.00%	0.00%
	Relationship with the consumer	1	1.69%	1	1.69%	0	0.00%		100.00%
Business model uncertainty	Revenue Template	5	8.47%	2	3.39%	3	5.08%	38.46%	40.00%
	Marketing strategy	7	11.86%	2	3.39%	5	8.47%		28.57%
	Pilot production	1	1.69%	1	1.69%	0	0.00%		100.00%
Total		59	100.00%	22	37.29%	37	62.71%		

Figure 5: Comparison between initial, resolved, and unresolved uncertainties

Source: The authors.

Thus, analyzing Figure 5 considering these exclusions, it can be seen that:

a) The subcategory, "process quality" was the one that presented the highest level of mitigation, with 100% of the uncertainties resolved. Soon after, "knowledge and team profile" appeared with 60%, both related to the resource uncertainty category. It can be inferred from the progress observed that the adoption of LS practices contributed to identifying points of improvement in the quality process, pointing out weaknesses and shortages of professionals, and providing improvements in the knowledge and team profile.

b) The subcategories "technology protection" (category of technology uncertainty) and "revenue template" (category of the business model uncertainty), both with 40%, appeared as the third ones that presented the highest level of mitigation. Regarding technology protection, we observed that the practices do not act directly on this uncertainty, but by stimulating those involved to think about the market and competitors, awakening them to the need for technology protection. Regarding the revenue template, the results indicate that the practices can contribute to the definition of the model since the characteristics of the technology, the product, and the market are analyzed to define it.

c) Comparing the number of unresolved uncertainties, the subcategories that had the most unresolved uncertainties were "product design, product value attribute" (product uncertainty category) and "market segment" (customer uncertainty category), both with 10.17%. It should be noted that these subcategories were the ones that presented the lowest level of mitigation (14.29% and 25% respectively), indicating that the adoption of LS practices did not present good results to mitigate these uncertainties.

5. Results and discussion

The most present uncertainties initially identified were related to resources and products, which is in line with the existing literature. Unlike established companies, startups initially do not focus on making the necessary resources available, and prefer to take advantage of improvisation in a short time (Huang *et al.*, 2022; Ye and Mai, 2018). The same happens about the product since startups do not test their business model and products before launching, unlike more mature companies (Ghezzi and Cavallo, 2020).

The main contribution of the research was to identify the uncertainties most worked on by the development teams of nine technological innovation projects, from the application of LS practices. It was observed that the LS practices contributed significantly to the reduction of uncertainties during the development of the projects, however, because they were applied simultaneously, it was not possible to identify their individual contributions. As demonstrated by the analyses, they contributed mainly to the mitigation of uncertainties in the resources category. Through the progress obtained about this category, specifically related to the subcategories of knowledge and team profile, process quality, and resources obtainment, it can be inferred that the practices contributed to identifying the weaknesses and shortage of professionals and were able to direct the search for knowledge and research information to improve the team's profile.

Reis *et al.* (2022) show that the use of LS practices leads the team to a positive increase in entrepreneurial skills, while Ladd and Kendall (2017) report an increase in the will and self-confidence of individuals exposed to LS to start new businesses. Other studies point out that due to the dynamic scenario in which they are inserted, there is faster learning by the team (Prashantham and Floyd, 2019; Xiong, Yang, Jia, 2019). LS practices have also shown great contributions to mitigate resource uncertainties since projects optimize and efficiently allocate resources to make quick decisions (Ye and Mai, 2018; Cunha, Cunha, Kamoche, 2003), and seek to acquire and innovate new resources to face environmental changes (Vera and Crossan, 2005).

6. Implications, limitations, and conclusions

Taking into account the need to structure the process of technological innovation and implement practices that help the team to overcome the barriers experienced in the development of products and companies, an intervention process was carried out in nine technological projects participating in the IPP at a Brazilian public university. As the projects aimed to transform their technologies into innovations, a set of LS practices was systematically applied by the project team, to help to mitigate uncertainties and, consequently, process waste. In addition, it was observed that the use of these practices allowed better management of the types of uncertainties experienced by the project teams, also contributing to the operationalization of the different phases of the project's process of technological innovation.

As a result, it was observed that the application of LS practices contributed mainly to reducing the uncertainties related to the subcategory "process quality" and "knowledge and team profile". Another finding is that most of the time when the issue of the team's profile is resolved, either by hiring people or forming and empowering people already in the team, these actions end up resolving the uncertainties arising from the lack of resources.

As an implication for the professionals involved in each project, it can be seen that the reduction of uncertainties during the development of technologies helped to identify gaps related to 1) skills needed to compose development teams; 2) necessary product and technology attributes to serve the target market; 3) planning marketing strategies for the desired market segment; and 4) knowledge of the business model adopted given the elaborated marketing strategies.

As a limitation of the investigation, 3 aspects can be highlighted: i) only nine cases were researched, ii) the study was carried out only in the Brazilian context; iii) the study focused on academic cases, which demonstrates the need for expansion and validation in the context of private initiative projects and startups; iv) the research did not seek to evaluate the contribution of each practice individually to mitigate uncertainties, and the mitigation of uncertainties was the result of the joint use of LS practices (Figure 1).

In future work, a longitudinal study is suggested that could provide more information about the contributions coming from the investigation, as it could evaluate the implementation of the defined strategies after the application of the methods. It is also suggested to evaluate the contribution of each lean practice individually. The results obtained can be analyzed based on projects and startups within the private sector, as well as on the reality of other countries. Other future works may investigate the relationship between the adoption of LS practices and Industry 4.0 principles, in an attempt to investigate the types of barriers associated with the

implementation of Industry 4.0 in the context of these business models.

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