Navigating Value Prospection to Favor Manufacturing in a Low-Complexity System from the Socio-Technical Theory

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Abstract. Implementing Lean Startup (LS) and Lean Product Development (LPD) can significantly impact innovation when developing new products and, consequently, the manufacturing stage. This study empirically conducts ideation and value prospection phases to favor the manufacturing stage in a low-complexity system of meliponiculture (stingless beekeeping) through the lens of socio-technical system theory. A case study was conducted through three main phases (ideation, value prospection and learning) by employing seven lean practices and involving more than 160 participants in a survey to conduct hypothesis testing. The findings from the application of the questionnaire were obtained through Cronbach's Alpha to assess the reliability and Chi-square to test the hypothesis. The study's findings state the importance of socio-technical theory in a low-complexity system, integrating LS and LPD to develop sustainable, customer-centered, viable bee boxes and informative booklets. It addresses a solution to

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promote income generation for vulnerable coastal communities, considering the interaction between social and technical aspects essential to support the manufacturing stage ahead. The study provides a holistic perspective through the interplay of people, technologies and the environment in the initial stages of product development to anticipate promising scenarios for effective and efficient manufacturing processes.

1. Introduction

The growing demand for consistent advancements in manufacturing has brought considerable attention to adopting lean principles (Hoppmann, 2015; Tortorella *et al.*, 2021; Castillo, 2022) since the initial stages of the product development process. This process has played a pivotal role in generating customer value within the realm of innovation while tackling the challenges of time, cost and quality dimensions, which are crucial factors for the development of innovative products (i.e. Lightfoot *et al.*, 2013; Vargha, 2018; Peralta *et al.*, 2020b; Battistella *et al.*, 2023).

Nevertheless, there are obstacles to adopting innovative methods in developing cutting-edge products. The challenges are often linked to cost commitment (Bocken and Snihur, 2020; Ghezzi, 2020; de Faria *et al.*, 2021). Notably, Lean Startup (LS) and Lean Product Development (LPD) have encountered resource constraints as two methods affected by this limitation. There is a notable scarcity of studies and practical applications regarding the LS and LPD (Lermen *et al.*, 2018; Sakai, 2018; Andersén, 2021; Summers and Scherpereel, 2023). However, existing research tends to address LS and LPD in isolation, with limited evidence of their combined application to anticipate manufacturing outcomes. Furthermore, most empirical studies focus on high-complexity industries, leaving a gap in understanding how these approaches can be adapted to low-complexity systems with resource constraints.

The significance of LS is undeniably intertwined with Lean Manufacturing and the processes of product and service development (Ghezzi and Cavallo, 2020; Yilmaz *et al.*, 2020; Lermen *et al.*, 2023). Empirically, LS is an approach focused on reducing resource expenditures in areas that do not significantly contribute to customer value creation (Felin *et al.*, 2019; Graciano *et al.*, 2022a; Blank and Eckhardt, 2023). Ries (2011) outlined six steps for implementing LS to avoid wasting efforts in the early stages of product development. The steps are (i) validated learning, (ii) Build–Measure–Learn (BML) feedback loop, (iii) minimum viable product, (iv) innovation accounting, (v) pivoting or persevering and (vi) continuous deployment (Reis, 2011).

In turn, LPD encompasses methods and measures that facilitate the application of Lean principles throughout the product development process (Marodin *et al.*, 2018; Belvedere *et al.*, 2019; Ucler and Gupta, 2021). After analyzing all available resources, LPD can provide insights into the distribution of surplus resources (Rivera and Chen, 2007; Todeschini *et al.*, 2017; Khosravi *et al.*, 2023). Although there is a growing demand for consistent advances in the development process of innovative products, there need to be more studies and practical applications related to the LPD. Recent studies indicate aspects of interest in LPD, such as (i) product

development, (ii) supply chain, (iii) shop floor management and (iv) after-sales service (Romero and Rossi, 2017; Chávez *et al.*, 2019; Lermen *et al.*, 2020a). Implementing LPD in these topics is only possible with the learning from lean manufacturing (Wickramasinghe and Wickramasinghe, 2017; Zhang *et al.*, 2017; Saad *et al.*, 2023).

In light of these gaps, this study examines how LS and LPD can be integrated during the ideation and value prospecting phases to facilitate manufacturing in low-complexity systems. We draw on Socio-Technical Systems (STS) theory to analyze the interplay of social and technical dimensions, addressing not only the theoretical gap but also the practical need for sustainable income generation in vulnerable coastal communities. In this context, our research aims to integrate practices of LS and LPD throughout the value ideation and prospecting phases to favor the manufacturing stage, using an empirical case in a low-complexity system of meliponiculture (stingless beekeeping) within the socio-economic scenario of Brazil's Southern coast. The study was based on the model proposed by Peralta *et al.* (2020a), which counts on five main approaches: (1) Lean Innovation, (2) LS, (3) LPD, (4) Customer Development and (5) Customer Value. Following the adoption of this initial approach, a framework was developed to identify and assess customer value creation, following the five phases and 13 practices outlined by Peralta *et al.* (2020a). Following the empirical creation of Minimum Viable Products (MVPs) 1 and 2, seven practices were put into action: (1) brainstorming, (2) focus group, (3) lean canvas, (4) stakeholders map, (5) value proposition canvas, (6) hypotheses testing and (7) hypotheses validation.

For the achievement of theoretical leaps, this study drew support from the STS theory (Soliman and Saurin, 2017), which is set to analyze the findings from the empirical case and to evaluate the dimensions of the model created by Lyytinen and Newman (2008). This model involves mapping technical features, tasks, actors and project and institutional structures. Considering the manufacturing lens, further discussion on the project's operational complexity and competitive profile is also provided.

The remainder of this paper is structured as follows. Section 2 presents the theoretical background on LS, LPD and STS theory. Section 3 details the research methodology and case study design. Section 4 reports the empirical results from the ideation, value prospection and learning phases. Section 5 presents the findings through the lens of STS and lean, Sec. 6 presents the managerial and practical implications and Sec. 7 concludes with theoretical and managerial implications, limitations and avenues for future research.

2. Theoretical Background

The traditional research and development methods have encountered limitations when applied to innovative projects since the requirements are rarely well-defined at the initial stages of the development and manufacturing scope. This study addresses the innovative methods of LS and LPD, which have the potential to greatly enhance

(a) Lean Startup

(c) Socio-technical approach

(b) Lean Product Development
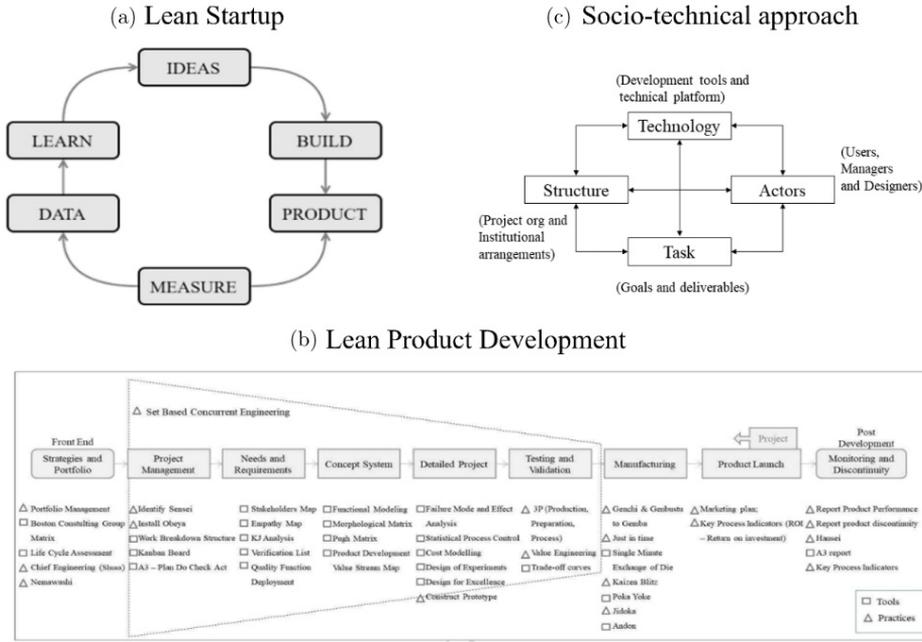
Source: Lean Startup (Adapted from Ries, 2011), Lean Product Development (Lermen *et al.*, 2018) and Socio-technical model (Lyytinen and Newman, 2008).

Fig. 1.   Frameworks and models employed.

innovative manufacturing practices through a Social–Technical (S–T) system theory perspective. Such approaches are represented in Fig. 1.

2.1.   *Lean startup*

LS was presented by Ries (2011) as a new method based on lean thinking (i.e. eliminate waste, short cycle time, small batches and involve customers early in the process) to assist entrepreneurs in building a successful startup. Along with lean recommendations, Ries (2011) advocates that LS can be applied to companies of any size, sector, or industry. This method has been mainly adopted by startups and spin-offs (Hwang and Shin, 2019; Harms and Schwery, 2020).

Ries (2011) introduced the BML loop as the core of the LS model (Fig. 1(a)). The BML loop begins with the startup's founders developing the business model grounded on a primary idea. Subsequently, they formulate hypotheses to be tested with customers seeking feedback (Ries, 2011; Eisenmann *et al.*, 2012; Powell and Oliveira, 2021). Typically, Business Model Canvas (Osterwalder and Pigneur, 2010), Lean Canvas (Reis, 2011) and Value Proposition Canvas (Osterwalder *et al.*, 2015) are usually employed to support entrepreneurs in formulating and validating hypotheses.

The initial testing of hypotheses focuses on the problem-solution fit, which validates the central problem, the most plausible solution, the target market and the

customer perspective. This validation is accomplished by engaging with potential early adopters through interviews, observation, or surveys (Bosch *et al.*, 2013; Blank and Dorf, 2020; Graciano *et al.*, 2022b).

Following the problem-solution fit's validation, the product's first version, the MVP, should be released to customers. The MVP is built with the minimum features and resources necessary to gather faster and more valuable customer feedback. The collected feedback can be analyzed through different tests, such as split or multi-variate testing (Ries, 2011; Lenarduzzi and Taibi, 2016). The insights gained from MVPs tests are intended to drive iterative advances and improvements to the solution (Lindgren and Münch, 2013; Gutbrod *et al.*, 2017). The validated learning acquired through hypotheses testing can lead to three essential outcomes: pivoting (making critical changes in the hypotheses), persevering (continuing on the same path), or perishing and abandoning the solution (Ries, 2011; Bajwa *et al.*, 2017; Ghezzi, 2019).

2.2. *Lean product development*

Derived from Lean Manufacturing, LPD has emerged as a transformative leap in companies' process management. As a natural extension of lean thinking from the manufacturing system to the product development process, no other approach has been able to match the innovative improvements observed in LPD (Liker and Morgan, 2006; Letens *et al.*, 2011), particularly in its emphasis on waste reduction from the early stages of product creation (Hines *et al.*, 2006; Johansson and Sundin, 2014).

The key topics addressed in the LPD literature include the identification of waste in product development processes (Nepal *et al.*, 2011), the adoption of tools and techniques for LPD to enhance efficiency (Hoppmann *et al.*, 2011; Letens *et al.*, 2011; Tyagi *et al.*, 2015), and the mapping the barriers to adopt LPD (León and Farris, 2011). Extending this scope, recent studies connect LPD to Product-Service Systems (PSS), consolidating the emerging field of Lean PSS, which combines lean thinking with the design of integrated product-service solutions and emphasizes continuous improvement across the entire lifecycle (Sassanelli *et al.*, 2019).

While tools and techniques from traditional product development remain important, lean-oriented ones, focusing on integration and coordination, are essential for promoting a seamless flow in the product development process (Letens *et al.*, 2011; Rauniar and Rawski, 2012). For instance, Lermen *et al.* (2018) proposed a framework for addressing the LPD. The framework (Fig. 1(b)) is composed of three macro-phases and nine micro-phases: (i) front-end (Strategies and Portfolio); (ii) Project (Project Management, Needs and Requirements, Concept System, Detailed Project, Testing and Validation, Manufacturing and Product Launch); and (iii) Post development (Monitoring and Discontinuity). Recent reviews also highlight that many of these LPD principles are increasingly embedded in the development of PSS,

giving rise to the concept of Lean PSS (Sassanelli *et al.*, 2019; Mourtzis and Angelopoulos, 2024).

2.3.   *Socio-technical system theory and low-complexity system*

The application of lean principles, whether in LS or LPD, considers the interaction between social and technical aspects within an organizational context. This perspective aligns with the STS theory, which recognizes the importance of considering people, technology and the environment to achieve effective and sustainable process performance (Sony and Naik, 2020).

According to the STS theory, organizations comprise four crucial and interconnected dimensions: technical features, tasks, actors and structures (Lyytinen and Newman, 2008), as depicted in the model of Fig. 1(c). These dimensions collectively shape the dynamics of an organization throughout the social and technical subsystems (Geels, 2022). This means that it is crucial to consider both the needs and abilities of people and the features and capacity of technology to create an environment that promotes collaboration and enables adaptability to change (Belhadi *et al.*, 2022).

S–T frameworks are "inherently dynamic and evolve via recursive shaping of technical infrastructure and social constructs, reflected in actions altering entities at the technical, task, structure and actor levels" (Kapoor *et al.*, 2021, p. 97). The S–T framework is well-suited for setting up a coherent understanding of how the social framework, including the network actors, adjusts/aligns objectives to bolster specific perspectives into technical landscapes. On the other hand, the technical lenses provide knowledge of how a framework meets specialized requirements. Still, they should also consider the intricate connections between an organization and the actors undertaking and supporting the complex business processes (Kapoor *et al.*, 2021).

Given that system complexity can impact system performance, it becomes essential to consider the holistic and integrative view proposed by the STS theory. When feasible, simplifying the system may mitigate the adverse effects of complexity. This is particularly relevant in configuring a low-complexity system (Lang *et al.*, 2014). Low-complexity systems refer to systems with limited elements and interactions with a simple and comprehensive structure (Wade and Heydari, 2014).

Specifically, Soliman and Saurin (2017) proposed a model to classify the complexity of a system when submitted to lean principles. The model combines the level of detail known about the business model under study (such as the number of workstations, employees, suppliers, product mix, etc.) compared to its dynamic complexity (e.g. dependence among activities, production routes, standard mode connections, shared resources and ambiguities). Systems can exhibit combinations of high or low levels of detail and dynamic complexity, resulting in their placement across the four quadrants shown in Fig. 2.
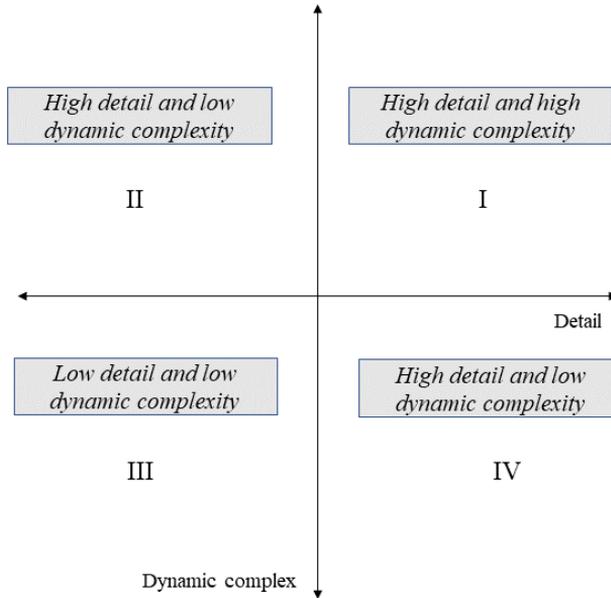
Source: Adapted from Soliman and Saurin (2017).

Fig. 2.   Classification of systems according to the level of detail and dynamic complexity.

This classification framework helps understand different systems, facilitating informed decision-making and adopting effective strategies, considering social and technical aspects accordingly.

3. Research Methodology

This section is divided into three subsections. First, we present a case study related to meliponiculture in Brazil. Second, we demonstrate the framework adopted in this study and its adaptations. Finally, we highlight suggestions for implementing LM in the case of meliponiculture.

3.1. Research scope

This research is centered around a single case study within the scope of meliponi-culture, focusing on beekeeping with stingless bees. Meliponiculture is a practice that presents potential value in various areas, such as food, health and aesthetics. Those benefits are intertwined with the components of honey produced by stingless bees (Chuttong *et al.*, 2016; Ribeiro *et al.*, 2018; Schvezov *et al.*, 2020). In addition to the tremendous socio-environmental importance of stingless bees, their representation in nature is equally remarkable. Although several studies on stingless bees have been published in the fields of food and chemistry (e.g. Biluca *et al.*, 2014; Ramón-Sierra *et al.*, 2015; Sharin *et al.*, 2021), we have yet not found empirical studies that

specifically apply this subject in management studies within the context of entrepreneurship, new product development and manufacturing.

According to the classification of systems using the S–T approach (see Fig. 3), the case study can be framed as a system with low detail and low dynamic complexity. This classification arises from the predominance of the beekeeper's manual activities, including the collection, storage and sale of honey. By focusing on a specific case, this research enables an in-depth exploration and more profound examination of the application of LS and LPD within the low-complexity system of meliponiculture.

The unit of analysis in this case study is the development of boxes suitable for stingless bees, which, unlike other species, have more complex and stratified nests. The components required for these boxes include two trays, an entrance tube, and a ventilation hole (Sharin *et al.*, 2021). Other extra features, such as bitumen and a surface with vegetation, are necessary for capturing and rearing the bees.

In this study, the startup dedicated to developing bee boxes aims to prospect value and promote the breeding of stingless bees as a revenue-generating activity. The startup operates at the intersection of the biotechnology and engineering sectors with four employees. Notably, the startup became well-established in the market with the support of a technological incubator affiliated with a Brazilian university.

3.2. *Methodological model*

In this study, we employed an adapted version of the model proposed by Peralta *et al.* (2020a) over four months. This model is a framework designed to emphasize value creation in innovative products. This study explores the phases of ideation and value prospection based on seven practices: four associated with ideation, and three pertaining to value prospection (Fig. 3). The aim was to create MVP1 and MVP2 for customer value creation and explore a learning phase (including the final decision step). Based on the structure depicted in Fig. 3, Table 1 presents the objectives and participants of each phase followed in this research.
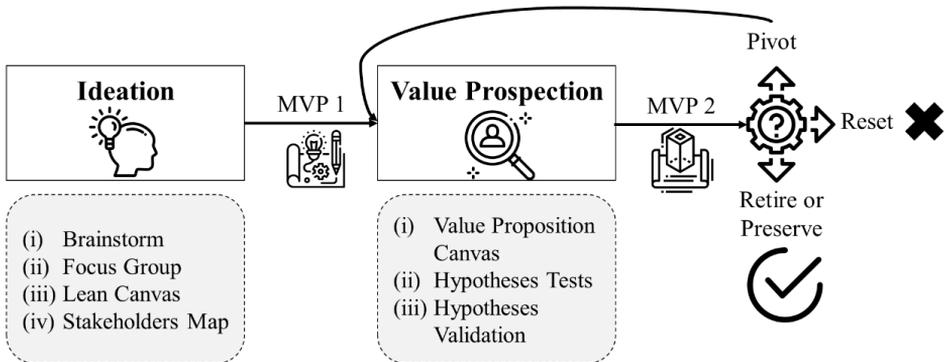
Source: Adapted from Peralta *et al.* (2020a).

Fig. 3.   Phases of ideation and value prospection.

Table 1. Description of tools and people responsible for applying the framework.

Phase	Practices	Objective	Participants
Ideation	Brainstorming	Raise ideas in the creation of innovative products in meliponiculture.	Two of the four startup's cofounders
	Focus Group	Identify and define the ideas from brainstorming that stood out and held significant potential for further development.	Four startup's cofounders and seven potential customers
	Stakeholders Map	Define the stakeholders that directly and indirectly influence the project.	All the startup's cofounders
	Lean Canvas	Define and visualize the potential solutions, gaps and business models.	
	Minimum Viable Product 1 (MVP 1)	Prototype the stingless bee box after data consolidation from the ideation phase.	
Value prospection	Value Proposition Canvas	Determine customer value and needs.	Four startup's co-founders and seven potential customers
	Hypotheses Tests	Propose hypotheses to be tested based on the inputs from the Value Proposition Canvas.	All the startup's cofounders
	Hypotheses Validation	Validate the issues addressed in MVP1 and the hypotheses from the Value Proposition Canvas.	
	Minimum Viable Product 2 (MVP 2)	The final prototype of the stingless bee box after data consolidation from the value prospecting phase	
Learning	Lean Pivoted Canvas	Pivot business model elements based on hypothesis validation and ensured customer value creation.	Two of the four startup's cofounders

3.2.1. *Ideation phase*

In the ideation phase, we initiated by engaging the cofounders of the focal startup involved in the meliponiculture project to propose ideas for bee boxes suitable to accommodate stingless bees. In sequence, we conducted a Focus Group (Puchta and Potter, 2002) involving seven potential customers with expertise in the environmental and socioeconomic aspects of the Brazilian coast (Curhan *et al.*, 2021). This session enabled us to brainstorm and gain initial insights into the perspectives regarding implementing the meliponiculture project. The input from the participants was explored to shape and define the ideas for the project moving forward.

The Lean Canvas (Nidagundi and Novickis, 2017) and the Stakeholders Map (Labanauskis and Ginevičius, 2017) were applied to complete the ideation phase. The Stakeholder's Map was collaboratively developed with the four co-founders of the startup to identify the stakeholders involved in the meliponiculture project and to understand the ecosystem's dynamics in which they operate. The Lean Canvas provided a structured framework to identify issues to be solved and the existing

customers, to define the product's value proposition before consulting the customers themselves, and to outline a proposal for the business model.

Based on the results from the ideation phase, a first MVP (MVP 1) was defined. According to Yaman *et al.* (2017), creating an MVP requires resources tied to potential customers' business goals, interests and possible "pains." Once choices and conflicts of interest were analyzed, it enhanced the validation activities of the MVP or explored alternative options to create value for potential customers.

3.2.2. *Value prospection phase*

Regarding the value prospection phase, three practices were employed to create the second MVP (MVP 2). The three practices are the value proposition canvas (Osterwalder *et al.*, 2015), hypotheses test, and hypothesis validation, which helped in identifying the customers' losses and gains, the formulation of hypotheses for solutions, and the subsequent validation of these hypotheses, respectively (Peralta *et al.*, 2020a).

The application of the Value Proposition Canvas was separated into three steps (Meng *et al.*, 2020). The first step was defining the customer profiles and identifying gains, pains and tasks. This step was conducted with the same focus group participants from the ideation phase. Second, it focused mainly on the products and services ideas derived from the ideation phase, along with the assumption of gains and pain relievers that could impact customers in the third step. Two meetings were held to meet the tool's requirements. The first meeting was conducted with the potential meliponiculture producers, during which insightful questions were posed to ascertain the customer profile. Building on the information gathered from the initial meeting, the second meeting was held with the startup's cofounders, culminating in creating a value map encompassing the products and services as well as gains and pain relievers.

Hypothesis testing and validation were performed using the approaches of "Test Card" (Shabbir and Wisdom, 2020) and market research (Gloet and Terziovski, 2004). The first one emerged from the customers' needs and desires hypotheses. The second depicted the creation of MPV1 for the customers through a survey. Consumers' perceptions were measured through questionnaires, leading to some adaptations in MPV2.

We developed a questionnaire in Google Forms® to validate the hypotheses (Appendix A). This instrument was composed of two sections. The first one corresponded to the customer's choice information of the startup regarding meliponiculture (interest in breeding, interest in the activity as a source of income, level of knowledge surrounding the activity, and interest in booklets and courses). In contrast, the second section explored their socio-economic profile (age, level of education, gender and income). The sample size was calculated following Li *et al.* (2020) sequence: (a) a 40% expected proportion of potential customers, (b) a confidence level with an interval of 95% and (c) a maximum estimation error considering the

error size of 0.05. Herewith, the sample required for data collection for this study was 135 respondents. We obtained a final sample of 160 respondents, positioning the survey within the requirements for validation and significance (considering the number of respondents residing on the southern Brazilian coast).

After collecting data, we calculated Cronbach's Alpha (Cronbach, 1951) to estimate the reliability of the questionnaire using six Likert scale questions. For the validation of the questionnaire, we obtained a Cronbach's Alpha of 0.869, which is higher than the minimum required (> 0.70) and below 0.90, attesting to the reliability and consistency of our data. Other factors identified were G6 (smc), which prioritizes results closer to 1. The G6 obtained was 0.8737, which is considered an acceptable value. Finally, the Average R, which identifies the average of all the information in the database, was 0.5304. Therefore, all recommended tests in the literature (Duhachek *et al.*, 2005; Shavelson, 2009; Taber, 2018) were performed to attest to consistency and reliability.

The Likert scale questions were applied after the hypothesis's validation, confirming the survey's consistency. Their answers were extracted from the questionnaire and tested using Person's chi-square function from the R Studio® software. The purpose was to understand the level of relationship and interference among Likert scale questions.

3.3. *Learning phase by lean principles*

The learning phase followed the LS application, as Ries (2011) recommended. This author argued that the accumulation of knowledge, insights and feedback be relayed to all parties involved. The importance of disseminating the lessons learned was emphasized to prevent wasteful decision-making in the manufacturing stage, and the team could make improvements and refinements in advance (Lermen *et al.*, 2020b). Learning from other lean applications (i.e. healthcare, office and construction) and frameworks that delivered customer value and enhanced the creation of MVP1 and MVP2 was necessary for implementing LS.

In this phase, the strategies for using Lean tools were defined after a meeting with all the startup's co-founders. Tools and techniques, as well as their customization for each product type, are essential in developing new products. For applying the framework in the development of stingless bees' boxes, the model selected for defining tools and practices was the framework created by Lermen *et al.* (2018), which served as a sequence of the original framework by Peralta *et al.* (2020a). The application can be adapted according to the level of detail and dynamic complexity (Soliman and Saurin, 2017).

4. Results

This section presents the study results following the phases and practices previously described.

4.1. *Ideation phase*

After conducting a brainstorming session to generate ideas for potential innovative products within the honey beekeeping niche, the startup's co-founders and potential customers of stingless bees' products participated in a focus group to further explore and raise emergent ideas. Based on that, the stakeholders' map was elaborated and is visualized in Fig. 4.

By visually depicting the key stakeholders that affect or can be affected by the meliponiculture project, the stakeholders' map served as a valuable reference for understanding the position of the various parties involved in the project. It is noticeable that the studied startup engages in partnerships with one university, one technology incubator, and multiple product and service providers, demonstrating a high level of maturity. The external direct stakeholders indicate how the startup
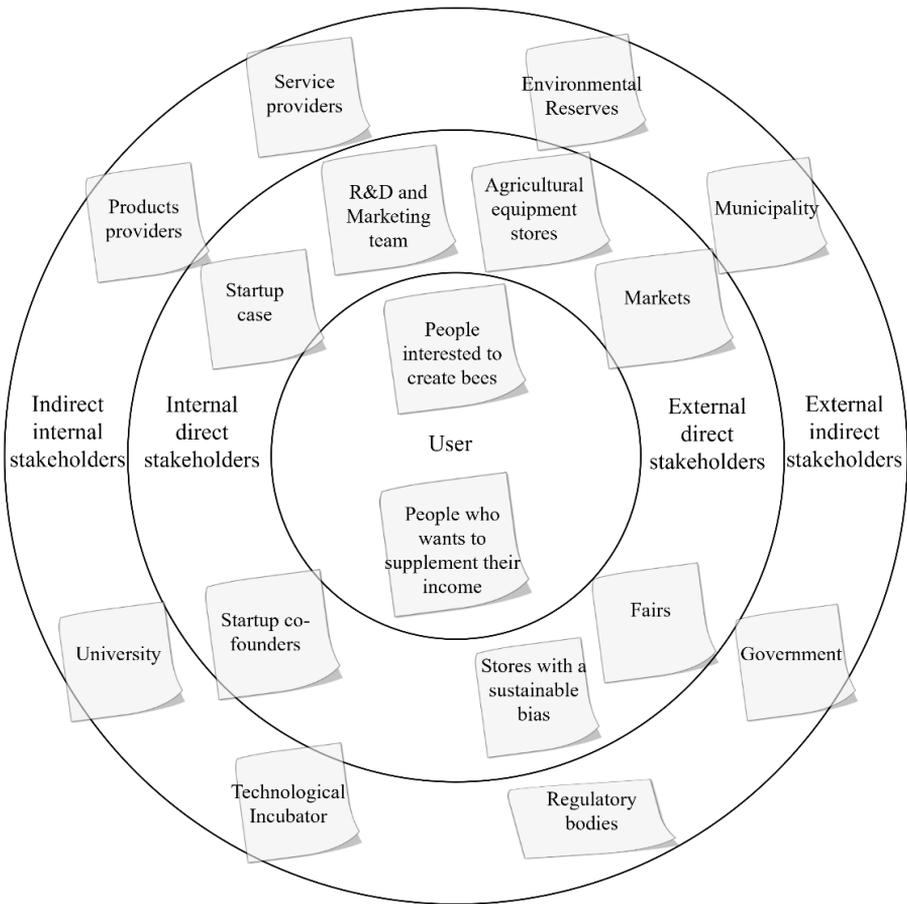

Fig. 4.   Stakeholders' map.

connects with its customers, such as using agricultural fairs, agricultural equipment stores, markets and stores with a sustainable orientation.

This avenue serves as a touchpoint for promoting the products and services to a broader audience and should be considered in the business model development. Drawing from the previous data collected, the Lean Canvas was developed with nine blocks within its structure, depicted in Fig. 5.

The Lean Canvas encapsulated the essential elements and information that contributed to formulating the business model for the meliponiculture project. The main problems faced by the startup include the high mortality rate of stingless bees due to environmental issues, limited knowledge of the species, and the difficulty in generating income on the Brazilian coast. To address these problems, focusing on the customer segment of small-scale beekeepers, the proposed solution for the project is a box with the appropriate size and easy handling for people interested in raising bees, along with courses and informative booklets to enhance knowledge on beekeeping dynamics. Finally, the startup's unique value proposition is aimed at preserving stingless bees while simultaneously creating a sustainable and economically viable source of income for the coastal population.

The ideation phase resulted in the creation of MVP 1. Figure 6 represents MVP 1, illustrating the efforts and insights obtained through the inputs of selected stakeholders involved in the project.

The MPV1 obtained was based on a product currently on the market, designed to accommodate all stingless bees. The box size measures $12 \times 24 \times 12\,cm$ (Length $\times$ Height $\times$ Width) and is constructed from sanded wood, ensuring a suitable environment for bees. Four divisions are included within the box, enhancing its
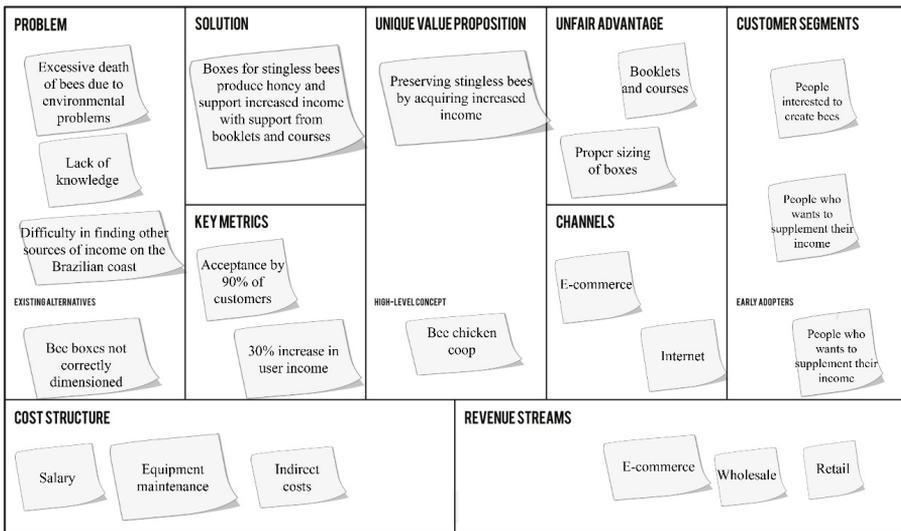

Fig. 5.   Lean canvas.

Fig. 6.   Minimum viable product 1 (MVP 1).

functionality for beekeeping purposes. However, MVP1 did not include handling at this stage, providing an opportunity for further refinement.

4.2.   *Value prospection phase*

Using Lean Canvas as a foundation, the value proposition was further elaborated and detailed in Canvas, as shown in Fig. 7.

Regarding the problems (pains) gathered from potential consumers related to the meliponiculture project, one notable barrier was the need for knowledge about stingless bees, which poses a challenge to expanding this activity. On the other hand,
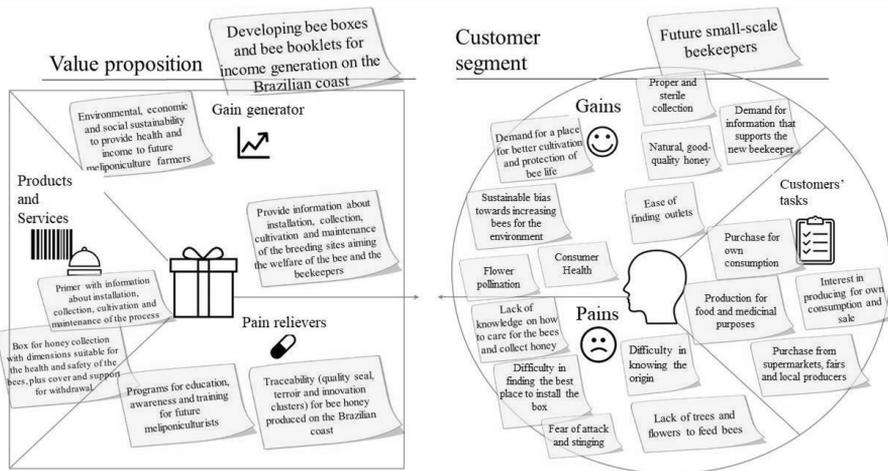

Fig. 7.   Value proposition canvas.

participants emphasized the importance of sustainable beekeeping practices, which is considered a crucial gain. The positive impact of pollination on flowers, high-quality honey and the demand for accessible information on meliponiculture were also considered vital gains. To address the identified problems and capitalize on the gains, a bee box was proposed, tailored to coastal species, a user-friendly bee box to is easy to handle, particularly for novice breeders. Courses and booklets could also be provided to address common doubts and questions on meliponiculture practices.

The hypotheses survey (Appendix A) was sequentially conducted using the Test Card proposed by Strategyzer (2015), depicted in Fig. 8. For H1, the selected questions from the survey were 2 and 13, associated with the classification of interest in stingless bee breeding and expected income. Regarding H2, the selected questions were 2 (classification of interest in beekeeping) and 6 (creation of booklets and courses to help potential breeders and customers). Finally, H3 associated questions 3 and 5, which addressed the interest in raising stingless bees as an extra income option and the interviewees' knowledge of bee breeding.

The Test Card was a structured tool and evidence-based approach to systematically assess and validate each hypothesis by applying a questionnaire. Regarding the respondents' profile, most were male (54.4%) and 73.1% reported being residents of Brazil's southern coast. Regarding the age range, it was identified that 36.3% of

Fig. 8.   Test card.

respondents were between 18 and 24 years old, 23.1% were between 25 and 34 years old, 21.3% were between 35 and 44 years old and, finally, 19.4% reported being older than 45. As for the participants' education level, most respondents, accounting for 43.1%, reported having an incomplete college education; 25.1% had an undergraduate degree, 20.6% had completed a college education and 11.2% reported having a graduate degree. The income distribution among the participants reveals that 30.6% reported incomes between one and three Brazilian minimum wages (R\$1,101.00–R\$3,300.00). In comparison, 35.1% declared to receive either one minimum wage or no stable income.

Understanding the socio-economic profile of participants was essential for understanding the target audience's composition and geographical distribution to resonate with the outreach strategies, tailoring communication and educational materials effectively, and focusing on assessing the proposed products and services.

In turn, Fig. 9 presents an overview of the survey results regarding the customer's choice of a startup regarding meliponiculture. Panel (9a) of Fig. 9 presents the interest in breeding, (9b) is the interest in the activity as a source of income, (9c) represents the level of knowledge surrounding the activity and (9d) depicts the interest in booklets and courses.

(a) Interest in breeding

(b) Interest in the activity as a source of income

(c) Level of knowledge surrounding the activity

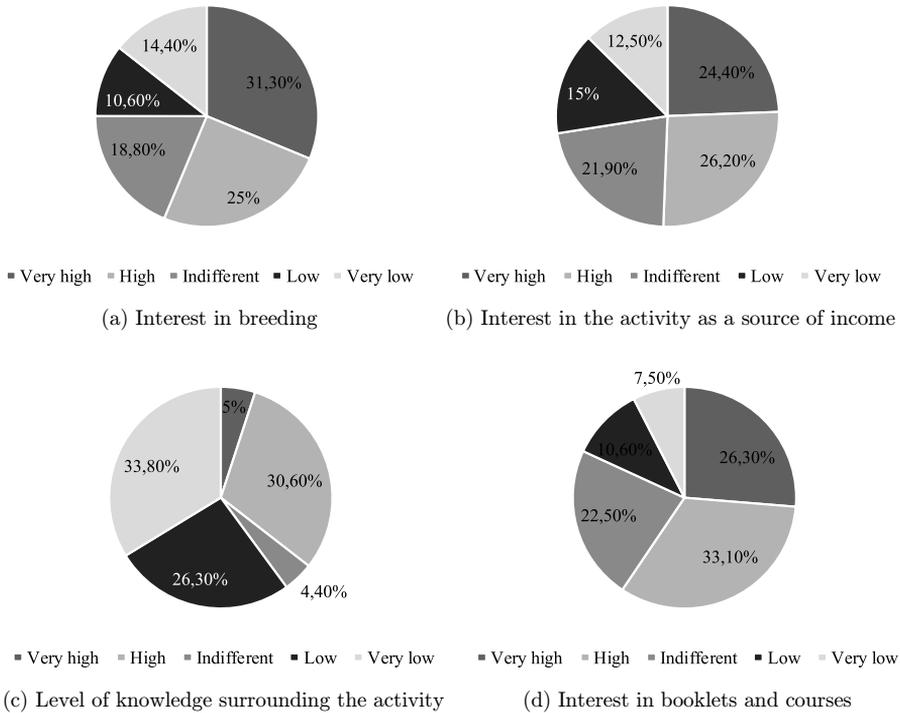(d) Interest in booklets and courses

Fig. 9.   Overview of customers' choice information.

A substantial portion of respondents, 56.3%, reported a high interest in bee breeding activities (9a). The interest in information about beekeeping as an extra income option (9b) resulted in a percentage of 50.6%. These high percentages of interest suggest a promising market potential for the startup's products and services related to meliponiculture.

The findings related to the knowledge (9c) indicate that 26.30% of respondents classified their knowledge as low, and even a larger percentage, 33.80%, as very low. Only 5% of respondents considered their knowledge to be very high. These results validate the significant knowledge gap among potential meliponiculture producers (startup customers), reinforcing the importance of providing training and educational resources, as Koethe *et al.* (2020) noted.

Finally, the interest in booklets and courses (9d) was indicated by 33.10% of respondents as a feature of high interest, and 26.30% of them expressed very high interest. The applied questionnaire also sought to assess the influence of booklets, courses and boxes on the respondents' decision-making process (Fig. 10).

In total, 51.3% of customers reported booklets and courses as highly influential in their decision to start beekeeping. This indicates that educational resources can effectively shape potential beekeepers' understanding and interest in meliponiculture practices. Similarly, 57.6% pointed to suitable and adapted boxes for the coastal species as determinant factors, which seems to be a crucial aspect that resonates with potential beekeepers.

These analyses supported H2 and H3 (p-value $= 0.000$). However, H1 did not receive significant support (p-value $= 0.0941$), i.e. no significant relationship exists between low income and the willingness to breed stingless bees. Based on insights gained from hypothesis testing and validation, MVP2 was developed, encompassing significant changes and improvements compared to the initial MVP1 (to support H2
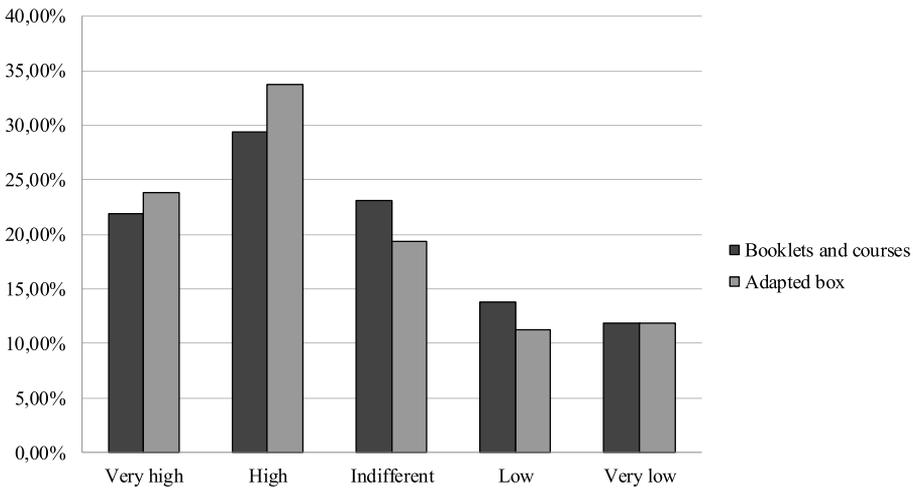

Fig. 10.   Level of influence of booklets, courses and boxes on the customer's decision.
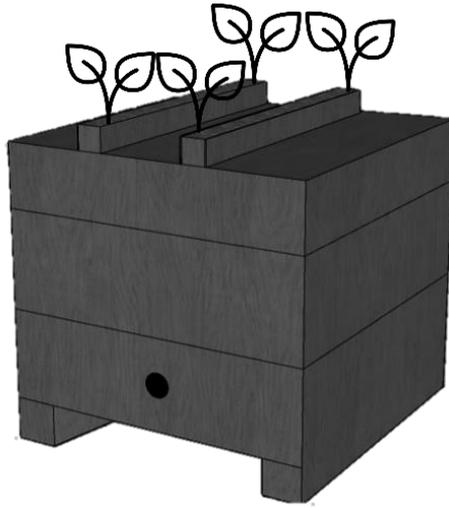
Fig. 11.   Adapted box prototype.

and H3). The MVP2 resulted in an easier-to-handle stingless bee box, including booklets and courses to disseminate knowledge about stingless bees, meliponiculture practices and sustainable beekeeping techniques.

Figure 11 illustrates the adapted box designed for stingless bees. The box model developed directly responded to the primary concerns identified during the ideation and value prospection phases, particularly the hypothesis testing and validation insights. Two important aspects were also addressed: the challenges of handling the box and the potential interference of plantations with honey production. Then, the team integrated a small planting space on the top protection of the box. The bee boxes have three compartments sized $31.0 \times 7.0 \times 2.5$ cm (Length $\times$ Height $\times$ Width). It is tailored to accommodate bees with medium-sized nests commonly found in the coastal regions of Brazil.

In Fig. 12, we present a proposed booklet for future meliponiculture producers. The booklet embraces regulations related to stingless bees, the proper capture process, and good handling practices. It was developed based on the challenges identified through active engagement with stakeholders and potential customers to foster a sustainable, manufacturing-oriented and legally compliant beekeeping venture.

4.3.   *Learning phase by lean principles*

Based on the iterative process of MVP testing and customer feedback, the pivot of the Lean Canvas was conducted to better align the business model with the specific requirements and learnings of the meliponiculture project. Key changes in the pivoted Lean Canvas included the customer segment, channels, cost structure and revenue sources. The changes are presented in Fig. 13 in grey color. Customers living
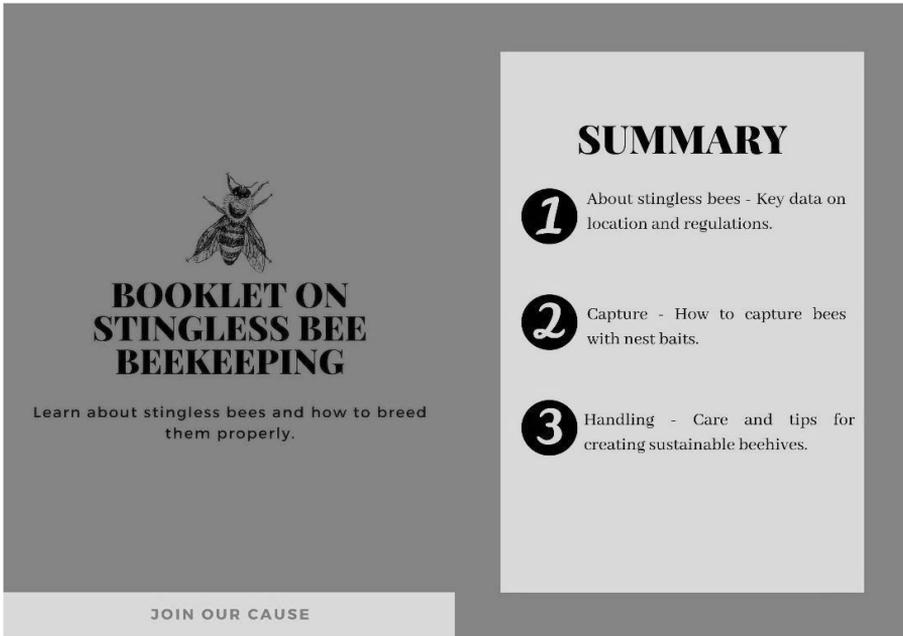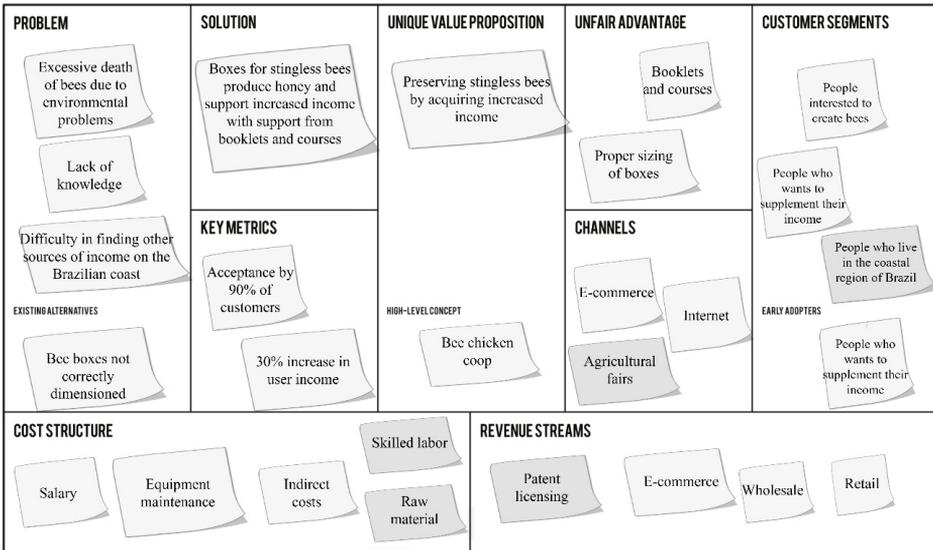
Fig. 12.   Booklet prototype.

Fig. 13.   Pivoted lean canvas.

in the Brazilian coast region were included. Agricultural fairs were added as possible channels. As a source of income, royalties from licensed patents were added, and raw materials and labor were included in the cost structure.

From a manufacturing perspective of the stingless bee boxes, the lean principles should be considered from the product development stage to ensure a streamlined and efficient manufacturing process, which also should be supported by lean manufacturing tools for standard work, continuous improvement and quality control.

By integrating lean principles from the product development stage, the startup can optimize resource utilization, enhance production flow and efficiently deliver products that meet customer needs. The learning obtained, especially from the construction and testing of MVP1 and MVP2, highlighted the significance of aligning manufacturing efforts with customer demands, the importance of an iterative approach for continuous refinement of product features and production processes, and the importance of testing and validating the value proposition before full-scale manufacturing.

5. Discussion from the STS Theory and Lean

The STS theory provides a valuable approach for analyzing the meliponiculture case study, particularly integrating the principles and practices of LS and LPD. Considering social and environmental implications and the technical aspects in the initial phases of the meliponiculture project has enabled a holistic approach to product development to favor the manufacturing stage.

The social aspects are initially related to the focus on the low-income population from the Brazilian coastal area that intends to generate extra income from stingless bees. The social perspective in the case study also involves identifying stakeholders (e.g. the startup's cofounders, potential meliponiculture producers and customers), their roles, and their interactions. Some factors related to an STS are the actors in the chain, such as providers, manufacturing industries and customers (Holt and Ghobadian, 2009; Martinez *et al.*, 2010; Demir *et al.*, 2023). The Stakeholders' Map allowed us to identify and understand the stakeholders and select the ones involved in the ideation and value prospection phases.

The focus groups conducted with the startup's cofounders and potential producers/customers also exemplify the application of the STS theory. By involving these relevant stakeholders, insights into the challenges and opportunities related to meliponiculture were gained, facilitating the ideation and value prospection activities. In fact, despite its complexity, startups' development of solutions based on technologies requires the participation of different stakeholders in the value chain to genuinely meet their realistic demands (Kirchberger *et al.*, 2020; Yang *et al.*, 2020).

Applying the LS and LPD made it possible to create an innovative and new solution and value proposition that addresses the customers' and other stakeholders' needs and preferences. The Lean Canvas and the Value Proposition Canvas, which

are used to define and refine the value proposition and the business model, also align with the STS theory. The startup created a comprehensive and customer-focused value proposition by considering the problems, interests and needs of customers and other stakeholders, addressing the social and technical aspects of the ecosystem.

Specifically, the technical aspects focus mainly on developing MVP1 and MVP2. By iterating and advancing from MVP1 to MVP2, a solution that is more complete, refined, efficient and adherent to customers' needs could be developed, positioning the startup for greater market acceptance in the meliponiculture sector. The final prototypes (adapted box and booklet) significantly contribute to local development by offering a sustainable and low-complexity alternative for income generation in coastal areas. The Lean Canvas supported consolidating how the solution featured through the MVPs can be delivered and the technical determination of the cost structure and revenue streams.

The MVP2 offers a more convenient and efficient beekeeping experience while contributing to the preservation of stingless bees and promoting sustainable practices. From the technical perspective, creating this MVP enabled us to anticipate the impact on manufacturing in terms of dimensions, precision, production sequence, efficiency and sustainability. Further manufacturing can benefit from incorporating this perspective, producing more adherent, sustainable and socially responsible products. This also encourages responsiveness and agility in manufacturing.

Based on the model of Peralta *et al.* (2020a), some lean tools can be incorporated to favor manufacturing, such as poka–yoke (Widjajanto *et al.*, 2020) in the development of the nestable support of the bee boxes and stability management (Pulliam *et al.*, 2021) to control the raw materials and processes during the construction of the boxes. Furthermore, the importance of employing visual management systems such as Andon (Knop, 2020) and Kanban boards (Powell, 2018) to control the productivity of the boxes could be considered. Regarding the production process, we suggest the application of the value stream map (Seth *et al.*, 2017) to understand the operation and period for each activity when producing the bee boxes.

Figure 14 illustrates a socio-technical model, based on the dimensions proposed by Lyytinen and Newman (2008), associated with lean principles to elucidate the main points in the empirical application of the STS theory to the case study.

The technology dimension is related to the prototype of the adapted box for stingless bees, which enables higher productivity and greater adaptability of the bees. It employed product design software, statistical software, forms and canvas adherent to LS and LPD. The actors' dimension encounters the focal startup and the low-income and environmentally-friendly population of the Brazilian coast that seek to generate extra income, as well as researchers involved in this study. The task dimension focuses mainly on the construction of the prototypes. Finally, the structural dimension of the project encompasses the funding agency, the startup that organized the project with support from researchers, and university counseling, making it possible to listen to the coastal population.
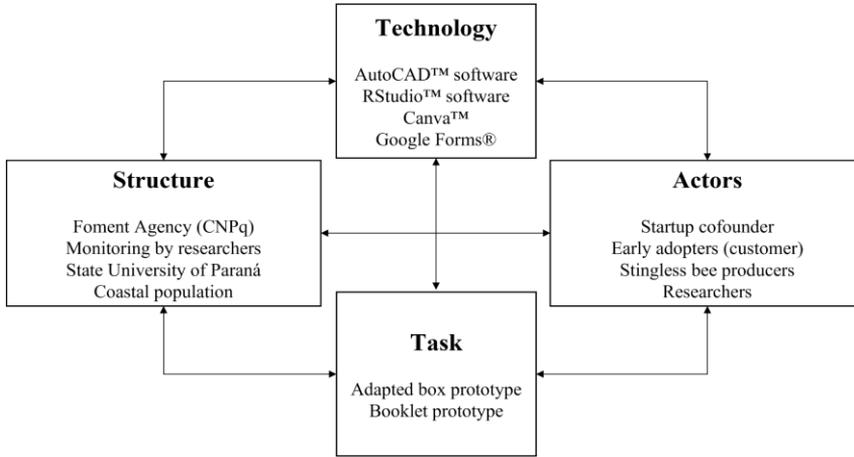
Fig. 14.   S–T approach and lean practices to the case study.

Building on the STS theory, the lean approach as a learning system usually adopts a Socratic approach, i.e. it seeks to promote a dialectical process based on the equality of power between learners (potential beekeepers) and a facilitator of lean learning (startup), allowing a relationship of learning and reflection among stakeholders (Saabye *et al.*, 2022). Organizations are expected to embrace superior adaptive and flexible capabilities (i.e. learning and innovation) to deal with the increasing speed of change arising from disruptions and transformation in the external environment, as is the case in low-income coastal communities. Correspondingly, the systematic and continuous learning by an organization practicing lean allows it to quickly adapt to its changing environment (Gutierrez *et al.*, 2022; Saabye *et al.*, 2023).

The low complexity of the system portrayed in this study facilitated the application of LS and LPD. Soliman *et al.* (2018) stated that studies implementing the lean approach in low-complexity systems should encourage reducing the number of variables and disruptions due to information and human-related issues.

Being a low-complexity system, the case allowed for utilizing readily accessible and available tools. The literature has emphasized this point, with several authors arguing that the level of difficulty in accessing tools and practices should be in tandem with the maturity level of product development (or innovation development per se) within a company (Capaldo and Rozenfeld, 2007; Bovea and Pérez-Belis, 2012; Fernandes *et al.*, 2016).

This study differed from the literature by conducting research focused on the case of low complexity since the other studies are focused on manufacturing industries of high complexity (such as Goretti *et al.*, 2023; Vlachos *et al.*, 2023). In addition, this study advances theory by proposing the integration between two approaches (STS and lean) and demonstrating the importance of stakeholder participation in the process, going beyond the simple involvement of manufacturing companies in the

early stages of product development, enabling the generation of positive impacts on the manufacturing process.

6. Managerial and Practical Implications

This study contributes to theory by demonstrating the potential integration between lean principles (precisely LS and LPD) and the STS theory in addressing the interplay between people, technology and the environment in product development under low-complexity systems. The STS theory provides a holistic perspective for startups and new organizations under low-complexity systems that had yet to be initially predicted. This study showed how lean principles can be applied to areas with limited resources, anticipating aspects to favor the manufacturing process. Finally, the research urges the importance of empirical-based studies in management.

This study's managerial contributions that entrepreneurs, managers and decision-makers can explore in product development and manufacturing are based on an adapted model, grounded on lean principles, to develop innovative products within a low-complexity system. Managers can draw inspiration from the practices and findings of this study when developing products that address societal, technical and environmental challenges. This study also aids managers in considering and understanding the dynamics between social and technical aspects in informed decisions from the initial stages of product development to favor the manufacturing stage.

7. Conclusions

This study explores the integration of LS and LPD in a low-complexity system focused on meliponiculture (stingless beekeeping) in the Brazilian South Coast. The ideation and value prospection phases were addressed using lean tools and practices, considering social and technical system perspectives.

The application of LS and LPD was made possible by adapting Peralta's model (Peralta *et al.*, 2020a), which had not previously been customized for low-complexity systems, such as beekeeping. Creating new products and identifying value for potential customers in the meliponiculture area has yet to be explored despite significant demand for such solutions. Addressing this gap, the value of prospection was essential to creating an innovative and user-centered prototype of bee boxes and informative booklets. Greater interest in beekeeping can be favored by projects linked to supporting vulnerable communities and sources of income associated with sustainable means.

The empirical case demonstrated the need to consider the interaction between social and technical aspects within an organizational context when developing new products that could favor manufacturing ahead. Integrating lean principles throughout the ideation and value prospection phases can help address customer needs and issues and offer an adherent value proposition. Rather than adopting a reactive approach of adapting products after launch, creating a compelling solution

for the target audience is essential. This ensures efficient resource utilization and is a proper antecedent to the manufacturing stage. At the same time, implementing this good practice may help reduce customers' resistance to acquiring new products and technologies, especially in meliponiculture, which demands training and education.

The main limitations include the single case study that allows for in-depth exploration but limits the generalization of the findings and cross-comparison with other case studies. This study also uses qualitative data from focus groups, and efforts to minimize bias had to be stressed. Due to time constraints, this study focused on the short-term outcomes of implementing LS and LPD in meliponiculture. Future research should explore long-term impact assessment, creating scenarios based on the prototypes and assessing the customers' willingness to pay.

Acknowledgments

Appendix A. Structured Survey

Section 1 — Interest in Meliponiculture

1. What is your level of interest in breeding stingless bees (meliponiculture)?

   ( ) Very low
   ( ) Low
   ( ) Indifferent
   ( ) High
   ( ) Very high

2. To what extent do you see meliponiculture as a potential source of income?

   ( ) Very low
   ( ) Low
   ( ) Indifferent
   ( ) High
   ( ) Very high

3. How would you evaluate your current level of knowledge about meliponiculture?

   ( ) Very low
   ( ) Low
   ( ) Indifferent
   ( ) High
   ( ) Very high

4. What is your level of interest in educational materials (booklets, courses, workshops) about meliponiculture?

   ( ) Very low
   ( ) Low
   ( ) Indifferent
   ( ) High
   ( ) Very high

5. What is your level of interest in acquiring or using an adapted beekeeping box?

   ( ) Very low
   ( ) Low
   ( ) Indifferent
   ( ) High
   ( ) Very high

Section 2 — Socio-economic Profile

6. Gender: Male/Female/Other/Prefer not to say
7. Residence: Southern coast of Brazil/Other (specify)
8. Age range: 18–24/25–34/35–44/45+
9. Education level: Incomplete higher education/Undergraduate degree/Completed higher education/Graduate degree
10. Monthly income (in minimum wages): No stable income/Up to 1 MW/1–3 MW/ More than 3 MW

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