

## Integrated technology roadmapping in startups: a case study of an AgTech in the Cachaça industry

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**ABSTRACT:** Companies develop strategies to describe where they want to go and how they will reach their destination. Business strategies are useful but may not be sufficiently detailed for areas of high importance, such as technology and innovation. In this paper we examined the effort of building a technology roadmap with an early growth stage company located in the state of São Paulo, Brazil. Roadmaps are easy to design yet flexible tools that can allow decision makers to explore a myriad of possible strategies. However, the challenges ahead for new companies facing uncertain growth scenarios demand that framework conditions be adequately addressed, and that innovation culture and technology management tools are integrated with the technology roadmapping strategy. Based on the empirical evidence collected from the startup studied, along with the literature and interviews with key stakeholders, this paper developed a pathway to support technology and innovation plans for startups going through similar growth stages and provides directions for future research in the area, given the scarcity of evidence available of new high-tech companies' efforts in planning and developing new products

**Keywords:** Industry 4.0, technology roadmap, cachaça, electronic-nose

### Introduction

Production and service provision systems of any kind have an irreversible tendency towards the introduction of innovations that help them devise new business models, products, processes and services with impacts both inhouse and on the market. Such a tendency triggers strategies and actions encompassing the development of technology solutions that can meet a firm's commitment towards the promotion of quality improvements, market expansion and profitability. However, despite the myriad of successful cases and experiences appearing in both the literature and the media, a number of production segments remain either resistant or have simply failed to understand how to capture the benefits of effective management of the process involving the development, diffusion and adoption of new technologies. This is the case of several companies operating in the agriculture value chain in developing countries such as Brazil, one of the world's largest agricultural players.

Following significant productivity gains achieved in agriculture and livestock production over the last three decades, Brazilian firms in every segment of agriculture are facing the challenges of growing in a somewhat highly uncertain and budget-constrained scenario that may continue in the coming years (Chaddad, 2016), and have had significant impact on both business models and corporate strategies (Phillips, et al., 2013). In response to this, state and federal public agencies are promoting financing schemes for the upskill of workers, tax deductions for firms conducting Research and Development (R&D) or acquiring capital goods, and sunk cost funds for joint translational research with universities and firms (Matos, et al., 2017).

As a result, small high tech firms in the agricultural segment, known as Agtechs, are growing in importance in the country as a response to, on the one hand, policy stimuli, and, on the other, to meet the demand of agricultural firms looking for cost-effective solutions that will assist them in dealing with productivity bottlenecks, increased competition, international penetration, and new product development challenges.

This paper focused on the technology planning and management efforts of an early growth stage firm operating in one segment that has been, for decades past in Brazil, a synonym for technological backwardness and social distress: the cachaça industry.

Cachaça is the exclusive denomination of sugar cane spirits produced in Brazil and is the most consumed distilled beverage in Brazil, and fourth in the world. The figures are not precise though estimates point to 11,000 producers being responsible for four thousand different brands of sugar cane spirits manufactured throughout this continental country (IBRAC, 2019). Additionally, in 2014 the sector generated 600,000 direct and indirect jobs and total revenues of US\$ 6 billion, followed by approximately 950 million liters of sugarcane spirits and cachaças produced nationwide, with an annual consumption of 6.3 L per person (Bortoletto and Alcarde, 2015). Following a recent premiumization tendency that is also affecting distilled spirits with effects on the increasing demand for quality products from both local and international consumers, producers are demanding solutions that can assist them in tackling challenges such as chemical composition requirements for entry in foreign countries, meeting quality standards as production volumes grow, qualification of the workforce, and sourcing advanced machinery and equipment to increase productivity.

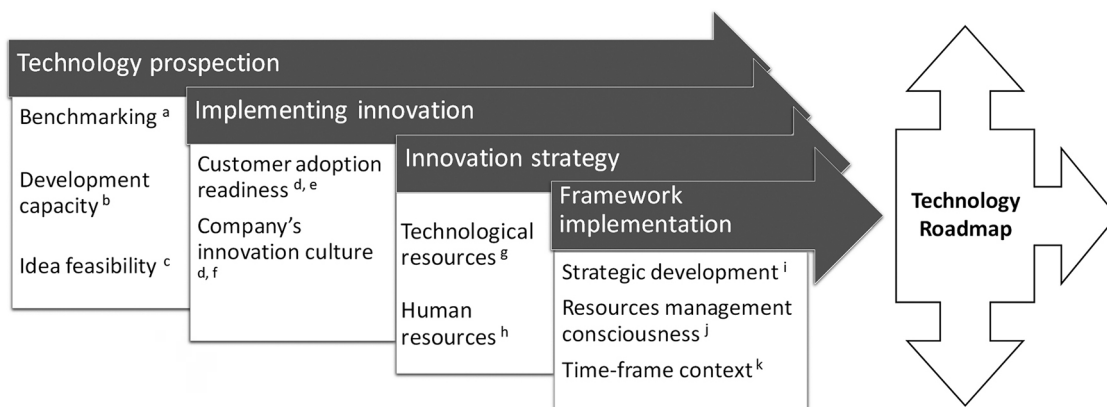
The startup in this study is IT Beverages. The company, whose roots are PhD research conducted at the School of Agriculture “Luiz de Queiroz” of the University of São Paulo, Brazil’s most acclaimed agricultural research university, was financed by the São Paulo State Research Foundation (FAPESP) and was aimed at delivering a two-fold value proposition to cachaça producers, by combining a low-cost and technology intensive solution to optimize decision-making in the critical wood-aging process of cachaça manufacturing. The solution proposed was based on the concept of an “electronic nose”, which is expected to have potential applications in other distilled spirits segments too.

In order to achieve the mission of providing automated solutions for the production of distilled spirits following the Industry 4.0 concept for digitalization, automation, process integration and production chain traceability, a need was identified at IT Beverages, namely, to rely on innovation management methodologies to reduce risks in product development, design, testing and prototyping, all areas with potential room for misalignment with market expectations, and, therefore, failure. The process encompassed an investigation of internal factors that support innovation in the company, culminating in the identification of a company’s specific profile that, according to the literature, strengthens and readies a culture for innovation, along with external factors related to required technology development approaches and future scenario propositions. This process introduced a learning experience to the company that, combined with data obtained from semi-structured interviews with 15 participants in the University and industry, generated a technology roadmap that organizes key information supporting the firm’s technology development strategies. The aim of the roadmap is to provide decision-makers with a clear visualization of the phases and bottlenecks in the technology development process that permeates the firm’s mission towards automation of key phases in the production of distilled

spirits. This process is summarized in Figure 1 and is explained later in this paper.

The research carried out in this paper addresses an empirically observable and relevant innovation management phenomenon, at the intersections of the literature of product development and technology management. By analyzing technology development strategies in an AgTech startup, this paper attempted to fill a gap in the literature, given the scarcity of documented similar experiences from developing countries. Such scarcity of academic case studies exploring these themes is, on the one hand, influenced by the reluctance of entrepreneurs in providing information revealing details of the technological approaches underlying their business models (Botelho and Almeida, 2010; Alves, et al., 2018), and on the other hand, by the difficulties of reproducing the findings of a single case study based on exploratory research (Edmondson and McManus, 2007). As regards the first aspect, the company founder is one of the authors of this paper, which guarantees accountability of the information and data disclosed in connection with this research. The second, which is critical per se as a single case study which does not allow for broader generalizations, entails an effort from authors to make the results outlined in the paper supportive for future studies involving public policies and enterprise development strategies for Agtechs, which, given the importance of the theme, is not restricted to audiences from developing countries.

As 95 % of startups fall short of meeting financial and product development projections, and 99 % of the time, the reason indicated by entrepreneurs and investors was lack of planning and experience skills (OECD, 2019), we believe the discussions in this paper can stimulate debates on the barriers and challenges for technology management practices in Agtech startups. Therefore, this paper analyzed different technology and innovation management practices and discloses key elements for the implementation of a technology solution applied to the distilled beverages industry.



**Figure 1** – Constructive pathway considered for elaboration of IT Beverages’ Roadmap. (a) Sawhney et al. (2006); (b) Maidique and Zirger (1984); (c) Garcia and Calantone (2002); (d) Rao and Weintraub (2013); (e) Munnir and Phillips (2005); (f) Martins and Terblanche (2003); (g) Bidasaria et al. (2014); (h) Goffin and Pfeiffer (1999); (i) Lu and Weng (2018); (j) Schuh et al. (2017); (k) Phaal et al. (2004).

This research paper is structured as follows. First, we analyzed the innovation opportunities in the segment of interest and identify a new technology that can fill an important gap in the production of distilled spirits derived from sugar cane. Next, we identified the factors underlying innovative thinking in the company, including internal factors based on the concept of Innovative Building Blocks (Rao and Weintraub, 2013). We then explored the current state of innovative mindsets among employees, along with strategies required for effective technology implementation. The following step involved an in-depth analysis of the technological landscape, which allows for an understanding of possibilities and scenarios that generate strategies leading to value creation. This step culminated in the analysis of the current status of the distilled beverages industry, which resulted in the identification of a lagged scenario whereby new solutions are increasingly needed to keep up with the pace of industry 4.0 challenges and opportunities in the value chain of distilled spirits production.

Next, the roadmap method was presented, merging all previous information with the strategic thinking required to design a chronological cadence of fundamental steps to achieve IT Beverages' goals. The future projection of events acts as a link between technology generation requirements and product release. We also understand that, from a long-term perspective, innovation processes must be able to adapt to new trends and circumstances that appear along the way. Therefore, and departing from a speculative point of view, circumstances conducive to mindfulness and open innovation are envisaged as part of a construct to help overcome difficulties in the technology development process of a startup. We dedicated the last section of the paper to presenting final remarks and recommendations.

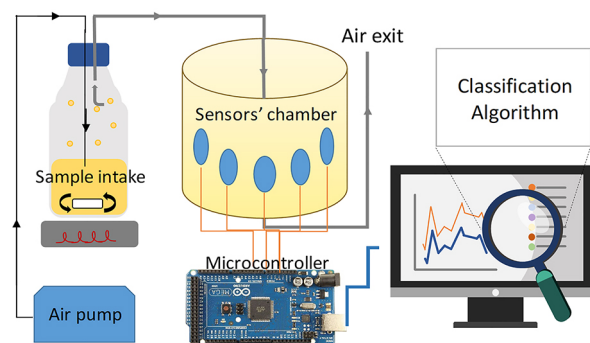
### Organization and innovation: Identifying innovative use of technology in operations, products and services

The first step consisted of an investigation into existing technology processes available. The objective was to understand which alternative paths the company could follow to achieve a certain desired future position in the market. With regard to the main bottlenecks related to technology, processes, marketing and internal organization, we questioned stakeholders in the academic world and industry on the strategies needed by IT Beverages to offer innovative IT-based products and solutions in the distilled beverages market. The discussion evolved towards an understanding that any IT-related solution aimed at promoting industrial transformation relies on the connectivity of ubiquitous technologies (Internet of Things, IoT) in order to integrate business processes and engineering functions that promote efficient and sustainable production systems (Wang, et al., 2016; Ciuffoletti, 2018; Wang, et al., 2019).

As a response, the company chose the development of a new technology covering areas such as raw materials, quality assurance, real-time process control, and bottling standardization. The idea behind the solution envisaged is based on existing gas sensors forming the e-nose concept, or 'digital olfactometry', which will collect a myriad of key data throughout the cachaça production process.

An e-nose is a piece of equipment that emulates human olfaction using gas sensors in a sample chamber (Figure 2). The electronic signal is imported into a classification algorithm that uses Artificial Intelligence (AI) for the characterization of a beverage sample according to a database (Loutfi, et al., 2015). E-nose technology is primarily focused on wood-barrel aging processes for the manufacturing of Cachaça, which today represents a subjective process relying on the expertise of one trained employee, the 'Master Blender'. Subjective or low-precision input data for process control can lead to errors, resulting in lower system performance response or in an increase in production costs (Kahn et al., 2003; Leo et al., 2002). The use of an AI-based algorithm aims not to substitute, but to provide the team with new inputs based on data collected upstream in the production value chain.

According to Coherent Market Insights (2018), a consultancy, a compound annual growth rate of 11.7 % is expected for the e-nose market until 2026, covering industries as varied as food and beverages, environment and health (Market Research Engine, 2019). Although there are already companies in this market such as *Alpha MOS*, *Odotech* and *E-Nose pty*, their technologies focus on analytical solutions for general-purpose applications based on huge datasets applied to different food matrices and isolated compounds. This creates opportunities not yet exploited, such as in the distilled beverages industry. The considerations emanating from this evaluation led us to one question, which answers the required influence strategies we obtained for the identification of alternative paths and risks in the e-nose technology deployment processes: which type of innovation does IT Beverages aim to introduce in its target market?



**Figure 2** – Schematics of e-nose basic prototype operational system.

Abernathy and Clark (1985) offered an interesting perspective on product classification, called "niche creation". This classification entails the renewal of a well-specified technology to target a new and specific market application. We can also describe this niche creation idea for the distilled beverages segment as product innovation based on technical contents (Maidique and Zirger, 1984), which is an innovation based on the recombination of existing components to display a completely new type of functionality. As product innovation targeting a market niche in a developing country, an e-nose for the Cachaça industry is idealized as a discontinuous innovation, or a "game changer" according to the Rice et al. (1998) definition, since it encompasses technical and market assumptions leading to potential increases in performance through new algorithms and AI tools, as well as proposed cost reductions for clients of at least 30 %.

Recently, certain local startups have been developing solutions to existing problems in the Brazilian beverage industry, which match Atuahene-Gima (1995) "newness to customer" classification of an innovative offer. To name but a few, *Smart Yeast* is developing microbiological products applied to the fermentation process; *Tecdef* and *InovBev* are active in the technological, legal and regulatory upskills of personnel in both the distilled and fermented beverage industries, and *Cachaça Gestor* provides IT management tools for inventory and sales control. By interviewing entrepreneurs in the startups mentioned in this paragraph, it became clear that IT Beverages' success involves the identification of a "newness to customer" solution (Atuahene-Gima, 1995) that can bring potential discontinuity to a marketplace not yet covered by established firms (Garcia and Calantone, 2002). As a result of this investigation, we found no single startup offering an assimilated digital olfactometry solution applicable to the beverages industry.

Sawhney et al. (2006) presented 12 dimensions to successful innovation, summarized by what the firm is offering, to whom the firm is providing the innovation, how the firm is providing it and where. Based on this conceptual tool for innovation/innovativeness quantification, they proposed an "innovation radar" encompassing all 12 elements into a somewhat 'big picture' framework. Following the interviews carried out and the inputs from the literature, we were able to depict an innovation radar for the company, as presented in Figure 3.

The innovation radar was built under IT Beverages' current position, considering average rates given by the stakeholders interviewed from academy and industry. These stakeholders were confronted with future perspectives whereby an e-nose concept should be deployed. The radar analysis displays strong innovation capacity related to Offerings and Solutions, which is related to the type of technology under development, as compared to current technology solutions available to the Brazilian Cachaça industry.



**Figure 3** – Innovation radar (Sawhney et al., 2006 elaborated for IT Beverages based on interviews and authors' elaboration).

The platform component also presented lower rates. This result relates to Brazilian Small and Medium Enterprises' historical low rates of technology adoption and innovation (De Negri and Rauen, 2018). The cachaça industry is no exception, as producers also appear reluctant to implement IT solutions, mostly due to low computer literacy (Daniel, 2016) and difficulties in properly balancing the trade-offs between implementation costs and the benefits obtained by the adoption of technology (Choi and Moon, 2013; Martins, et al., 2018). As a result, the customer component also displayed a lower score. As a response to these potential risks affecting the e-nose technology implementation process, IT Beverages incorporated the principles described by Kearns, Taylor and Hull (2005) into its deployment plan, by including frequent prototype tests and aggregation of human factors such as the user experience into the adaptive improvements of its e-nose technology.

The Customer Experience component reveals the possibility of change in this scenario through the development of a user-friendly interface, followed by a successful adoption of IT Beverages' products by key-customers that may encourage the use of e-nose by more resistant cachaça producers. IT Beverages' proposed grounding structure for operations led to a higher Process and Organization rating, given the novelty of the e-nose proposition to this industry. The Supply Chain item poses significant challenges to the effectiveness of technology implementation, given the myriad of risks and bottlenecks involved in the deployment of a package such as e-nose which consists of embedded semiconductors, software and hardware (Figure 2). Consequently, the critical networking component is required by means of addressing partnerships with other companies that offer complementary services and solutions in the beverages industry, some of which have already been mentioned in this section of the paper.

**Analysis of company’s innovative capacity in using, adopting and generating innovation**

It has been widely acknowledged that the culture of an organization is an important driver of innovation and creativity (Lundy and Cowling, 1996). A creative organization encourages valuable ideas in different spheres of the company, encompassing products, processes, services and procedures (Martins and Terblanche, 2003) towards the promotion of a vision and mission oriented to the future (Covey, 1993). In a study conducted by Rao and Weintraub (2013), corporate culture was found to be more important to innovation than either labor, capital, government, or national culture. From this perspective, the processes leading to planning the development and implementation of a technological innovation require that the organization understands what constitutes an innovation culture and how culture can lead to innovation. Our understanding of a corporate culture is as simple as the view of Lundy and Cowling (1996, p. 169) for whom the culture of the organization is “the way we do things around here”.

According to Rao and Weintraub (2013), an organization’s cultural framework encompasses six main blocks: Resources, Values, Processes, Behaviors, Success and Climate, of which at least one has to be fully consolidated for innovation. After surveying the stakeholders interviewed, we formulated an innovation readiness summary presented in Table 1. This summary allowed for the identification of certain bottlenecks to be addressed by the company which are discussed further.

As the case in point refers to an early growth stage company, it comes with no surprise that Resources is the factor that demands most attention. In fact, IT Beverages pays compelling attention to its limited resources such as Time, Money and Space (Rao and Weintraub, 2013). As a response, a detailed business plan presenting e-nose’s business model and its value proposition strategy to potential sources of financing can reduce the risks that this factor might become detrimental to the company’s sustainable growth.

Despite belonging to different blocks, “Behaviors” and “Success” relate both to approaches of individuals in the organization. The Behavior block points out the need of recruiting a workforce whose profile, attitudes and values are aligned with the company’s mission.

The Success block, on the other hand, involves the establishment of a culture in the organization that embeds learning opportunities within its reward and feedback mechanisms, regardless of results achieved.

For dealing with a costly, though essential, learning instrument to any organization, such as failure, a positive approach is required to enhance the team’s knowledge over failed undertakings of which generated learning can capitalize on successful projects later. As a response, the company plans to conduct internal symposiums with members of the organization, industry and academy to foster the exchange of ideas and experiences. The ecosystem to which IT Beverages belongs is important to this end. The company is situated in a very dense environment comprising Agtechs in various stages of the agricultural value chain, public and private research universities, large national and multinational firms, and support organizations such as science parks and startup accelerators. This all lies within a 10 km radius from the IT Beverages location, and certainly contributes to Values not being such a serious bottleneck in the firm’s growth, according to respondents.

After creating an environment that sustains innovation creation, it becomes necessary to develop and implement the ideas generated. After considering that a favorable innovation culture is in place, the effectiveness of the implementation process requires precious investments in time, financial resources, internal training, users’ support, continuous monitoring, team meetings and evaluation (Klein and Knight, 2005). As regards New Product Development (NPD) efforts, intra technical innovations yields a better performance according to five main factors originally specified by Cooper and Kleinshmidt (1999), namely, process, strategy, organization, culture and management commitment. Based on an extensive review of the literature and field research, Adams et al. (2006) proposed a framework based on seven categories, known as: Inputs, Knowledge Management, Innovation Strategy, Organizational Culture, Portfolio Management, Project Management, and Commercialization.

The measure of inputs for innovation implementation is accessible through the human resources count, which is the number of people directly involved in developing new solutions, equipment and analysis, divided by their absolute numbers (Cooper, et al., 2001). Knowledge management processes cover the phases of opportunity identification, analysis, and idea generation, followed by concept selection and development (Koen, et al., 2001) Innovation strategy analysis can be accessed by measurements of alignment between the company’s structure and production systems (Bessant, 2003), or between the strategic objectives and innovation goals (Tipping and Zeffren, 1995). Portfolio management entails the firms’ efforts towards effective allocation of material, human and financial resources. This is implemented through a framework – either qualitative, quantitative or mixed – leading to operational

**Table 1** – Building blocks (Rao and Weintraub, 2013) for IT Beverages organization culture implementaion, ordinated according to innovation readiness score.

Bottleneck importance	Building block	Composing factors
More relevant	Resources	People, Systems, Projects
	Success	External, Enterprise, Individual
	Behaviors	Energize, Engage, Enable
	Processes	Ideate, Shape, Capture
↓	Climate	Safety, Simplicity, Collaboration
Less relevant	Values	Entrepreneurial, Creativity, Learning

and financially effective new products or service platforms (Cooper, et al., 2001). Project Management practices require the application of measures that identify, analyze and monitor planned versus realized activities, usually with cost, schedule, operability and safety as the main success indicators (Morrow, 2011). The Communications component implies that an open channel is in place and that it encompasses all stakeholders involved in the innovation project, internal or external, and that the company has a defined framework allowing for the right information to be available to the right person at the right time (Parthasarthy, 2002). The definition of roles and responsibilities is a key element to this end.

The last stage of innovation implementation entails the launch of a new product. According to Adams et al. (2006), the "Commercialization" category consists of turning an innovative product into a commercial success through relentless marketing, distribution, and sales strategies. Measurement tools for the commercialization of innovation are scarcely according to the literature, even though Verhaeghe and Kfir (2002) highlight market analysis, planning and constant monitoring as strategic capabilities contributing to more successful products that manage to reach their target markets.

Therefore, IT Beverages needs to gather both tangible and intangible resources, processes and tools that can help it achieve successful implementation of its e-nose innovative approach. Departing from the challenging establishment of a culture of innovation around its internal resources, a critical issue consists of identifying the parameters required for monitoring its innovation development and implementation processes.

Hence, the evolution of its organizational structure may be frequently monitored, and eventually reassessed to guarantee alignment with its desired goals.

From the literature review and interviews with key stakeholders, who outlined potential risks and barriers for a successful implementation of technology such as e-nose, the innovation management tools required to increase the chances of a more effective technology delivery were identified and summarized in Table 2.

The set up of the internal innovation management competencies, as shown in Table 2, is key to any high-tech organization, either new or established in the market. However, as pointed out by Munnir and Phillips (2005), the success of new technology and its diffusion is not necessarily associated with its newness or the effectiveness with which it is designed, tested and implemented. Instead, they argue, it may also be related to the discursive activities surrounding the market and how the firm manages to reach the social context where the innovation will be deployed. In the context of internationalization of innovative activities, being mindful of a firm's key attributes is of interest to any startup dealing with technological, organizational, financial and market uncertainties. A mindful firm "attends to an innovation with reasoning grounded in its own organizational facts and specifics" (Swanson and Ramiller, 2004). The key attributes of a mindful organization, according to Sternberg (2000) are: (a) openness to novelty; (b) alertness to distinction; (c) sensitivity to different contexts; (d) implicit, if not explicit, awareness of multiple perspectives; and (e) orientation in the present.

**Table 2** – Management measurement components for IT Beverages' innovation implementation according to categories proposed by Adams et al. (2006).

Framework category	Measurement in IT Beverages
Inputs	<ul style="list-style-type: none"> <li>- number of innovation team members</li> <li>- ratio of number of members involved with innovation development over total employees in the company</li> <li>- financial amount for innovation projects</li> <li>- ratio of innovation budget over general budget</li> </ul>
Knowledge management	<ul style="list-style-type: none"> <li>- number of patents registered</li> <li>- number of ideas proposed to upper management</li> <li>- ratio between all ideas generated and those that became products/ solutions</li> <li>- number of active projects</li> <li>- number of concluded projects</li> <li>- number of filed/discontinued projects</li> <li>- sum of all projects (all-in)</li> <li>- ratio between filed projects and total number of projects</li> </ul>
Innovation strategy	<ul style="list-style-type: none"> <li>- deadline commitment for milestone (percentage of in-time achieved over all deadlines)</li> <li>- innovative alignment and engagement of employees (qualitative aspect)</li> <li>- innovative alignment of projects</li> </ul>
Portfolio management	<ul style="list-style-type: none"> <li>- selection of higher Product Innovation Index (Pi2)</li> </ul>
Project management	<ul style="list-style-type: none"> <li>- cost efficiency: quotient between expenses in current state of a project and budget allocated</li> <li>- time efficiency: quotient between time expended in current state of a project and foreseen workhours</li> <li>- team efficiency: quotient between achieved tasks in a current state of a project and overall tasks in same timeframe</li> <li>- number of meetings for new ideas discussion</li> <li>- ratio between new ideas meetings and overall meetings</li> </ul>
Commercialization	<ul style="list-style-type: none"> <li>- online Purchase Intention forms</li> <li>- prospecting market gaps through social medias</li> <li>- creating an interactive interface for collecting data of interest</li> </ul>

Mindfulness in organizations entails developing cognitive behavior patterns that help a company deal with harsher environmental conditions such as growing competition, elevated customer expectations, and market factors leading to "demand for high performance standards, lower error tolerance, turbulence and complexity" (Weick, et al., 1999). The adoption of new technologies at IT Beverages is strongly rooted in hardware and software development. Moreover, the company consists of a domain facing growing national and international visibility, such as the adoption of AI and algorithms of data science, all indispensable to IT Beverages' e-nose technology. A significant market-making effort will be required, which entails marketing, pricing, and positioning strategies, in order to positively intervene in the cultural barriers towards the utilization of such technologies by Brazilian cachaça producers.

Embedded sensors in industrial plants are key concepts of industry 4.0 (Jang, 2016; Kang, et al., 2016; Lu and Weng, 2018; Lee, et al., 2015). Creating a connected environment in an industrial facility leads to process optimization, real-time production and control, and effectiveness in equipment utilization (Schug, 2018; Evans, 2015). Therefore, food and beverage companies are currently more concerned about implementing new technologies for process monitoring and efficiency successfully, with new windows of opportunities appearing in different segments of the production chain (Schug, 2018; Rodriguez Gamboa, et al., 2019). Being mindful of these coming challenges is therefore key to e-nose development and successful implementation. We will exploit this further in the following sections.

#### **Innovative technologies suitable for IT beverages: Industry 4.0 innovation implementation**

AI can be an important ally of innovations in the beverage industry, given its pervasive role in technology-based production processes and influence on decision-making and monitoring of production systems.

Product estimation quality is based on patterns emanating from comparisons with similar samples available. The concept behind IT Beverages technology is that a significant amount of observed data will feed a database containing related AI learning processes over cachaça Quality Assurance (QA), allowing the system to recognize new "smelling patterns" (or fragrance printings) from all data points previously collected. The requirements for such technology integration consist of extensive data collected over assimilated industrial processes, together with connectivity to facilitate AI incremental learning (Wang, et al., 2016; Encinas, et al., 2017).

According to Wang et al. (2016), the radical change addressed by Industry 4.0 relies on ubiquitous information systems (IoT) connected in real-time, leading to a scenario of operational flexibility and potentially increased efficiency and sustainability (end-to-end engineering integration). Such intricate processes have

little chance of succeeding within the boundaries of a single startup. With regard to the implementation of e-nose technology, after the development and validation steps for a thorough characterization of cachaça aged in wood barrels, its application all the way through different processes within the cachaça industry will depend on establishing solid partnerships. IT Beverages is therefore building local ties with important players in the academic world and the market such as the University of São Paulo's Laboratory of Technology and Chemical Quality of Alcoholic Beverages, consultants and Brazilian distilling facilities and bottling companies. At this point, financial and legal support is required, demanding suitable mindful strategies for weighing up the pros and cons of sharing sensitive information with potential investors, collaborators, business partners and customers.

Therefore, the e-nose concept will evolve based on sensitive and critical data collected from different distilleries which, after a consensual data sharing policy, enter a Computing, Communication and Control process, or 3C process, as observed by Wang et al. (2016).

Another starting point for implementing an AI-based solution within an industrial facility involves the development of a multiagent system (MAS), which consists of an intermediate intelligent decision-making structure that merges human and computer-controlled processes. This concept is known as "augmented intelligence" (Ford, 2015), and involves human and machine working complementarily (Kurzweil, 2005). Considering Schug et al.'s (2017) maturity process, six steps are required for the implementation of an autonomous system: computerization, connectivity, visibility, transparency, predictive capacity, and adaptability. The first two correspond to the traditional digitalization efforts required for industrial automation. The last four, in sequence, represent the building blocks of an Industry 4.0 autonomous system.

In addition, the implementation of new technology built on industry 4.0 foundations may also consider four aspects described by Lu and Weng (2018), namely, sensors, integration, intelligent and response systems. Considering cachaça is a market that suffers from competition from internationally established spirits like whiskey and gin, coupled with rudimentary industrial practices that, in a myriad of low tech producers, can generate contaminants (Bortoletto, et al., 2018), the few modernized Brazilian producers of cachaça are eager to adopt solutions that can address such specific and complex issues (Martins, et al., 2018). Additionally, government schemes are now coming online, with the Ministry for Agriculture engaged in a myriad of programs to support the development of this industry through new regulations, supply chain, marketing, R&D and innovation support initiatives (MAPA, 2011). The opportunity envisaged by IT Beverages encompasses an effort to help the industry adopt the concept of connectivity and data handling to improve product quality, process efficiency, and equipment effectiveness.

**Innovation strategy: Linking people, operations, products/services and IT with growth and competitive edge**

According to Bidasaria et al. (2014), a lead role of R&D initiatives targeting innovations consists of merging both technical and commercial skills to support complex decision-making based on knowledge and expertise from across all company sectors. This is no easy task as it demands a thorough implementation strategy supporting opportunity framing, scope selection and definition (Cooper, et al., 2001), which can be harsh on early growth firms with limited resources.

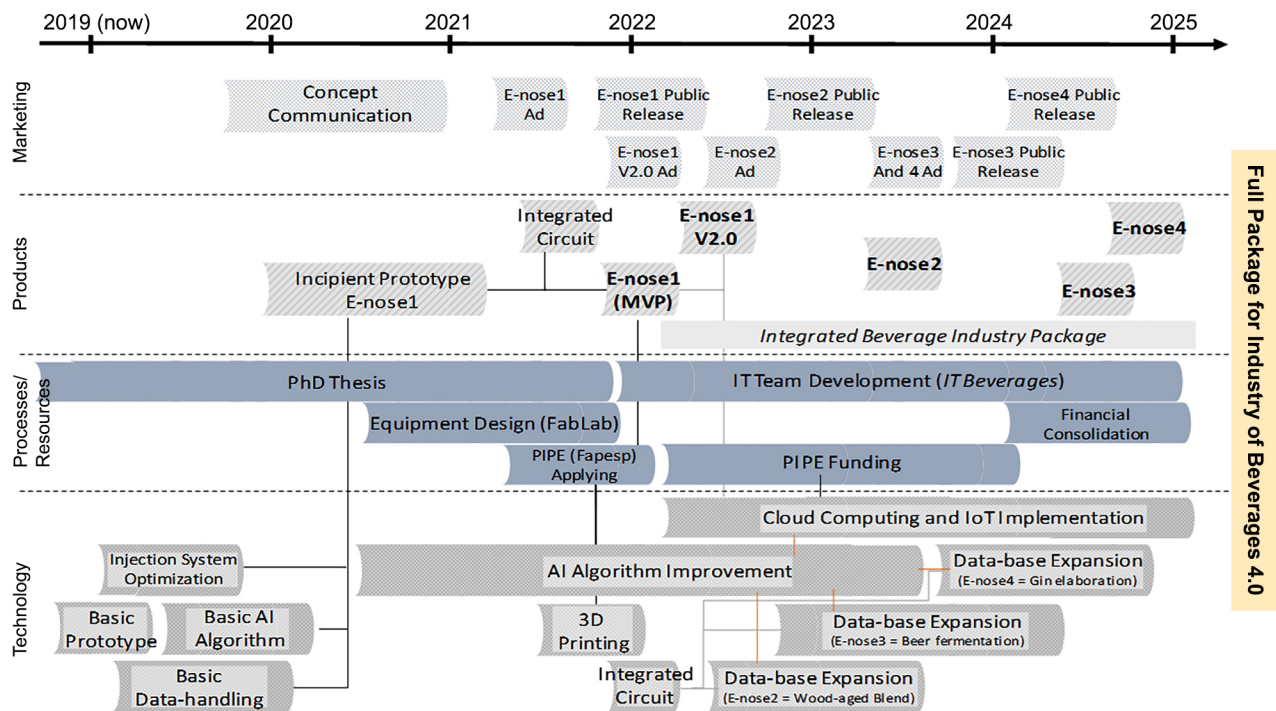
Roadmaps have emerged as an attempt to help companies face challenges in project planning and implementation. A roadmap is an efficient and flexible method for implementing different types of projects within plural niches of knowledge, in variable time-frame terms, and with multiple purposes, providing decision-makers with flexibility and adaptability during critical path execution (Rinne, 2004). In this paper, we focus our attention on the concept of technology roadmap introduced by Phaal et al. (2004), defined as "a structured (and often graphical) means for exploring and communicating the relationships between evolving and developing markets, products and technologies over time". Both technology roadmap and roadmap terms are used interchangeably in this paper.

As a strategy formulation tool relying on critical multilayer and multilevel features (Bidasaria, et al., 2014), roadmaps merge development of attitudes and

built-in project, product, process, company and/or market characteristics in a defined time-line, clarifying and explaining the intricate processes leading to the development and consequent implementation of technological innovation (Lu and Weng, 2018).

According to Phaal et al. (2004), the elements used to build a technology roadmap are not limited to but are strongly dependent on the following: i) time-frame, normally the horizontal Cartesian dimension in a roadmap designed to suit a particular situation. The scale used depends on a company's present vision and position; ii) top vertical layers, related to market approach, or "know-why", designating factors leading to value creation; iii) bottom layers indicate companies' "know-how", which corresponds to consolidated or in-development technology and applied knowledge; iv) intermediate layers comprise the carriage agent who delivers knowledge and technologies to meet market needs, namely "product development strategy"; v) links between components of different layers may be useful to provide a perspective of existing dependency or relationship between concomitant or successive processes. Additionally, codes and notations may help visualize specific paths.

Based on the review of product and technology management literature, the taxonomy and features of technology roadmapping and the interviews conducted, we present IT Beverages' Technology Roadmap in Figure 4. The purpose of this roadmap is to link technological needs with new product development efforts in order



**Figure 4** – IT Beverages' Roadmap built for development of technologies until 2025 providing solutions and products for Beverages Industry 4.0.



to support IT Beverages' mission of being a major player in technology development and automation in the Brazilian distilled beverages industry. It should be noted that both product and technology development, together with required processes and resources are highlighted to contextualize each phase necessary to achieve IT Beverages' aim, as well as marketing and market aspects determining major risks to the capture and creation of value. The Technology Roadmap presented in Figure 4 emphasizes the myriad of critical technology and product development bottlenecks discussed earlier, as well as market forces affecting product demand and acceptance the company decision-makers will need to tackle before the firm can meet its five year expectations.

The selected areas determining the layers of IT Beverages' technology roadmap are based on the criteria proposed by Phaal et al. (2004), consisting of a two-fold market dynamic, namely, Market-Push and Market-Pull. Market-pull ("Marketing" layer in the roadmap) focuses on value creation through innovative products and marketing actions that enhance value perception. Market-push embeds a series of actions produced by the company's mission and its main technologies ("Technology" layer), resources and processes required for the company to meet its desired outcomes. Lying between both top and bottom layers, the intermediate "Processes/Resources" layer corresponds to the materials and methods employed to develop the envisaged technological solution. The "Processes" component represents the path along which financial, human and intellectual resources intertwine to create and improve technology development practices. A critical process identified in this layer involves the financial resources for the consolidation of IoT cloud computing infrastructure and the AI algorithm improvements, along with their sub-components (Štefanič, et al., 2019). Because of the inherent risks in these processes, IT Beverages will count on its partnership with the Laboratory of Technology and Chemical Quality of Alcoholic Beverages to obtain further resources from FAPESP's sunk-cost funding scheme for early-stage startup and university translational research, the PIPE Program in its two phases (PIPE I and PIPE II), as highlighted in the roadmap. The "Products" layer provides the link between required technologies, thereby merging the visualized components that provide a consumable solution to the market. This layer also provides a notion of which resources are needed for IT Beverages to meet the distinct needs of the distilled beverages industry under the umbrella of Industry 4.0 specifications.

As depicted in the Roadmap, IT Beverages' critical success components rely on developing and delivering a Minimal Viable Product, or MVP, herein represented as e-nose version 1.0, and on providing all the necessary conditions for increasing its value capture from the target market. Further, a fundamental structural change

in IT Beverages' operation involves the deployment of major financial and human resources to consolidate the company's position in order to display a series of new capabilities provided by improved versions of the e-nose software and hardware. Additionally, it will create a connected environment that integrates client's critical processes with the view of obtaining a comprehensive structure for information traceability and the organization of quality olfactometry data which will rely on solid partnerships with industry players to improve a critical path such as the market consolidation of the automation system underlying the e-nose main technology offer.

### **Innovative scenarios: future cases of IT innovation deployment**

In the event of a favorable scenario whereby IT Beverages becomes a key provider of high-tech automation solutions in the distilled beverages industry, the company, with sustained growth envisaged by the Technology Roadmap, will also rely on building other complementary assets. One possible strategy for companies in early growth stages facing uncertain critical paths both in product development and market acceptance is open innovation. Open innovation corresponds to an interactive practice between a company and its environment, assumed in order to take advantage of external knowledge to foment internal innovative ideas and solutions (Chesbrough, 2003; van de Vrande, et al., 2006).

As a future oriented construct, IT Beverages' open approach to innovation encompasses two key areas, highlighted in the Technology Roadmap presented in Figure 4 as follows: i) partnerships for collection and quality assurance of olfactometry data; ii) release of 'public coding challenges' in order to aggregate successful innovative approaches and solutions from other industry areas (e.g. marketing information, production management, business modelling, pricing etc).

Basic monitoring of the main parameters which influence the quality of cachaça production processes is carried out concurrently with e-nose's data collection structures using sensors containing significant amounts of data. Furthermore, data validity procedures rely on the quality and validity of the data previously collected. In order to obtain samples of interest, strategic partnerships with local producers become essential, as they rely on teams collecting field data appropriate sampling procedures that assure precise correlation between e-nose readings and applicable field conditions.

However, there can be risks in disclosing e-nose detailed project information to users of online platforms. IT Beverages' strategy consisted of gathering strategic data from key players in the academic world and industry to improve either one or more of the following steps: i) process control, such as properly

blending aged beverages to standardize products; ii) distillation fractioning based on online information of the volatile profile of the distillate; iii) development of software to assist in recommendations of the volume of each distillate to compose a final product through mixture; iv) signaling quality of fractions during distillation based on field data.

The next phase involved testing and grading facilities required for basic Good Manufacturing Practice (GMP), including issuance of motions of understanding and non-disclosure agreements over a shared information policy. After contributing data acquisition, the collaborators were invited to join a group benefiting from IT Beverages' technology built using their own data. Therefore, the analytical readings obtained and accurately analyzed were subsequently transformed into market and production-oriented data that feed an AI algorithm.

Accompanying the consolidation of the proof of concept phase, the results obtained were traded with partners as an intensive technology and accurate analysis made over their distilled beverages production processes. For example, e-nose is expected to provide partners and then clients with feedbacks such as: "Mix 20 % of the volume of barrel A with 80 % of the volume of barrel B to obtain a beverage that matches the standard sensory profile of the previous batch" or "High level of acetic acid detected in the distillate. Recommendation: collect this lower quality fraction in another container so as not to impair the quality of the beverage".

To aggregate market and sales information in the AI system, opened back-end challenges will be addressed with a global developers' network to discuss solutions that merge beverage production and market demand (Viejo, et al., 2019). The challenges proposed were to consider data available from social networks, such as user preferences over partner products (through citations of brand profiles or tags), as well as data on customer behavior over different beverages and brands throughout the year. The challenges were to be oriented towards the creation of AI-based tools for market-oriented solutions, such as determining the automated production schedule, inventory management and optimized product offer over the different seasons of the year, in order to minimize operating costs.

As a result of the challenges arising from shared data, open innovation can be useful by generating knowledge and technology assessment over market behavior, production trends, consumer habits, industry production capacity, autonomous portfolio management methodologies, and optimization techniques for data collection. Lichtenthaler (2011) described this approach as an outside-in process (though it is also known as external knowledge exploration), when he indicated the need for adequate management mechanisms concerning appropriate tools, processes and structures that lead to successful implementation of open innovation.

## Final Remarks

Technology roadmaps enable diagnosis of organizational challenges for technological innovation and provide companies with directions on how to best implement innovative technologies. However useful and critical to supporting strategy at corporate levels, in the context of early growth firms, the practical effects of the critical synthesis of the knowledge acquired through roadmaps may be hampered if certain conditions are not met. Startups need to desperately tap into all resources, such as working capital, qualified personnel, equipment and machinery, all of which are very scarce or non-existent in these firms. As we discussed previously, what is also critical is recognizing that company culture can be as important to innovation as other tangible resources. Not least, the choices over the paths along which the identification, selection, definition, development and operation of the technology will occur, together with managing the chosen path within acceptable cost, schedule, risk and operability constraints are also detrimental to successful innovation implementation. Roadmaps therefore have embedded a dense network of methods, tools and resources that new companies need to address in order to introduce successful high tech solutions in their markets.

By reviewing the literature and carrying out interviews with 15 individuals from the university, potential customers, partners, and members of the company team, we managed to construct a critical analysis of the efforts required to support technology development strategies in a new high-tech firm. As a result, this application of related theories and perceptions of key stakeholders helped the early growth stage company build capacity to gain insight from technology management and industrial developments, thereby championing practices and solutions that supported the elaboration of a technology roadmap.

The first practice utilized the innovation radar, promoted an overview of the organization's potential for generating new ideas and highlighted existing areas for improvement. This exercise demonstrated that awareness of the potential areas for internal innovation practices was vital to helping the firm generate more creative processes leading to market innovation. Aspects concerning culture fitting and mindful approaches were recognized as elucidative for achieving the results expected in the five-year timeframe considered in the roadmap. In addition, understanding global approaches to behavior patterns that lead to innovation has contributed to the implementation plan. Such approaches relate particularly to organization culture, in which a major challenge is to align the firm's goals with expectations and motivations of human resources. These practices support the setup of a deeper sense of embeddedness and satisfaction required for building a corporate innovation mentality that tolerates failure

and stimulates learning, accompanied by measurable success indicators supporting decision-making at all levels.

Roadmapping the development of an electronic nose in the company studied supported the determination of an exploratory step-by-step approach, consisting of the visualization of necessary resources over time and the identification of key improvements and developments required to achieve a technology deployment strategy. As a result, it was possible to define a parallel schedule for financial and marketing strategies supporting the firm's objective, as presented in the technology roadmap. During execution, roadmap flexibility will prove vital when dealing with environmental conditions and technical issues that may arise in the course of company growth, representing new inputs that need to be assessed and incorporated into the technology roadmap, if deemed appropriate.

Following discussions featured in this paper, company management concluded that the complex and uncertain path ahead of it demanded reviewing practices and strategies related to restrictive business policies that can hamper sustained growth. The reason was simply the difficulty recognized in counting on key in-house human and material resources that, although important, could not be sourced on a short or mid-term basis due to budgetary constraints and the overall local supply conditions of specialized workforce and suppliers. To alleviate this, open innovation was considered a possible growth perspective going forward. In addition to internal technology improvements, the aspect of external collaboration enriches community engagement and brings with it, at a relatively low cost, external perspectives that can contribute to the generation of new solutions. This strategy, obviously, comes at a considerable cost if the firm does not set up policies to ensure roles and responsibilities over the sharing of key and sensitive data with both internal and external supporters.

The case studied in this paper focused on identifying a pathway supporting technology development efforts in a pre-revenue, small high tech firm. By starting with technology prospection, it was possible to describe the dynamics of the company's industry, such as recent structural changes, anticipated future developments and the global landscape, and thereby elucidate the current role and status of innovation in the company. The success of this phase required a comprehensive coverage of the challenges and opportunities the organization faces along with the corporate response to technology implementation and utilization. Having identified the innovative technologies suitable for business purposes, the company studied was able to explain the potential benefits of adopting each of the proposed technologies, including anticipated improvements in productivity, products and services, collaboration, and project management. Next, the evaluation of corporate implementation of technologies inside the company required that the firm identify the

impact of failure on the company's innovation practices, and that it understands how technology management metrics contribute to successful implementation of innovations in the organization.

The company studied recognized that the roadmap was important in supporting its way through deploying e-nose technology in the market within five years. As a next step, market-oriented prospectations after the roadmap become vital to enhancing communication with the market and, consequently, aggregating value to the firm's future portfolio of products. The technology roadmap defined the timeframe for these actions, but the concrete pathway to be assumed has not been defined as yet.

Finally, as this is but a single case study based on a review of the literature and evidence collected by the authors from investors, researchers, potential clients and other entrepreneurs, this study does not allow for wider generalizations. However, given its scope as an exploratory study, we believe the discussion and results outlined will offer support and guide future studies in technology management in the context of startups. The authors also understand that upon attempting to provide this balance between theory and practice, we risk alienating either one or all of our intended audiences of entrepreneurs, academics, and policymakers. At the same time, we hope they appreciate the value of the approach developed and that, consequently, this study will serve peripherally to encourage and strengthen the development of a better understanding of the capital requirements of entrepreneurial firms amongst both academics and practitioners.

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## Authors' Contributions

Conceptualization: Silvello, G.C.; Alves, A.S. Data acquisition: Silvello, G.C.; Alcarde, A.R. Data analysis: Silvello, G.C.; Alves, A.S. Design of methodology: Alves, A.S.; Silvello, G.C. Writing and editing: Silvello, G.C.; Alves, A.S.; Alcarde, A.R.

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