TECH TO MARKET. FINDING AND DESIGNING SUITABLE TECHNOLOGY APPLICATIONS WITH DESIGN THINKING

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ABSTRACT

Although it's human centered focus, design thinking has proven to be effective also in technology-driven projects, both in education and business. Yet, scant research has investigated whether and how design thinking might be leveraged to find new opportunities based on emerging technologies and design new innovation concepts accordingly. To address this gap, we employed an Action Innovation Management Research framework and co-designed a program called Tech to Market with Oper.Space, the design factory for Open Innovation of the University of Bologna. We ran 5 iterations of the program from October 2018 to December 2022, in which we conducted 52 interviews, observed 10 presentations, and held 10 meetings with the main stakeholders involved. Our results show how to apply design thinking to find and design a suitable application for a given technology, contributing to the ongoing conversation about the implementation of design thinking in technology-driven projects.

Keywords: Design thinking, Design management, Design methods, Technology management, Innovation

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1 INTRODUCTION

Scholars studying technologies and technology development have long recognized the crucial role of different processes in finding and designing a suitable technology application (Magistretti, Dell'Era, and Verganti, 2020). The term "*finding a suitable technology application*" refers to exploring the opportunities of the technology and steering its development independently of the product (Savino, Messeni Petruzzelli, and Albino, 2017), while "*designing a suitable technology application*" involves embedding the technology developed into a new product, service, or system to solve a particular problem (Dell'Era et al., 2017).

Traditionally, the literature on technology development has addressed the finding and designing perspectives by analyzing linear sequences of phases that guide the process (Twiss, 1992) focusing on factors such as economic performance (Caerteling, Halman, and Doree, 2008), team competencies (Ghazinoory et al., 2017), and user needs (Garrety, Robertson, and Badham, 2004). However, more recently, scholars have proposed integrating linear processes with iterative approaches that allow for greater flexibility and collaboration among stakeholders, enabling faster adaptation to a changing context (Cooper, 2021). The underlying assumption is that such flexibility reduces uncertainty by considering different adoption scenarios for the technology, increases the opportunities considered, and enhances the likelihood of obtaining a breakthrough innovation (Magistretti, Dell'Era, and Verganti, 2020). These iterative processes are influenced by continuous customer involvement (Jha et al., 2017), allows for iterations and non-linearities in the process because of continuous changes in requirements and customer needs (Jha et al., 2017), and involves more frequent interactions with different stakeholders in the context in which the process takes place (Magistretti, Dell'Era, and Verganti, 2020).

In spite of the shift in focus from linear to iterative processes and the increasing emphasis on involving customers in iterative technology development processes, the literature remains limited in terms of when end-user involvement should take place in iterative processes and how organizations should handle this interaction with users (Magistretti, Dell'Era, and Verganti, 2020), both in education (Kim, Joines, and Feng, 2022) and business (Mahmoud-Jouini, Fixson, and Boulet, 2019). This paper seeks to shed more light on this gap in iterative processes and to investigate whether and how design thinking might be leveraged to find new opportunities based on emerging technologies (i.e., the finding perspective) and design new product concepts accordingly (i.e., the designing perspective). We selected design thinking because both marketing and R&D teams working on technology-driven projects often struggle to find and design a new application for a technology with their traditional tools and consider design thinking as a viable option for innovating (Mahmoud-Jouini, Fixson, and Boulet, 2019).

The remainder of the paper is structured as follows. In the next section, we present the theoretical background on design thinking and our research question. Next, we illustrate the methodology that we employed to address the research question. Then, we present the results of our study which show how design teams can apply design thinking to find and design a suitable application for a given technology. Finally, we discuss our findings, highlighting theoretical and practical implications, as well as future research avenues.

2 THEORETICAL BACKGROUND

Design thinking is "*a discipline that uses the designer's sensibility and methods to match people's needs with what is technologically feasible and what a viable business strategy can convert into customer value and market opportunity*" (Brown, 2008, p.2). This definition, which is one of the most cited in the design thinking literature (Micheli et al., 2019), emphasizes that design thinking looks at innovation through three lenses: desirability, feasibility, and viability (Brown, 2009). Desirability refers to whether the users will find the product/service compelling and how they will interact with it, feasibility concerns whether the solution is technologically feasible for the organization, and viability considers whether the solution is financially and economically viable for the firm (Carlgren, Rauth, and Elmquist, 2016).

Design thinking can be conceptualized as a process that involves five main steps[1]: empathize, define, ideate, prototype, and test. The first step in design thinking is to empathize with the people who will be using the product or service. This means understanding their needs and desires (Carlgren, Rauth,

[1] Stanford d.school. Design thinking bootleg

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and Elmquist, 2016). The second step is to define the problem that needs to be solved: in this sense, design thinking is one of the preferred ways of solving wicked, ill-defined problems, as it relies on discovery in advance of issues and needs (Buchanan, 1992). The third step is to generate the widest range of ideas for solving the identified problem (Seidel and Fixson, 2013). The fourth step is to prototype the ideas and make them tangible (McCullagh, 2013). The fifth and final step is to test the ideas with potential users to see if they work (Beverland, Wilner, and Micheli, 2015). Although scholars, leading design consultancies (e.g., IDEO) and design schools (e.g., Stanford Design School) use different terminologies and process visualizations to describe design thinking, in practice they all offer the same process scaffolding, which consists of collecting data on user needs, generating ideas, and testing them with users (Liedtka, 2015). That is, design thinking, whatever nuance considered, always starts from desirability to understand people and their needs (Dell'Era et. al, 2020).

Nonetheless, design thinking has proven effective even in contexts which are traditionally less focused on users, such as technology-driven organizations and projects (Mahmoud-Jouini, Fixson, and Boulet, 2019). Since the focus of our paper is on finding and designing a suitable technology application, design thinking is here examined as an approach to innovation "*that draws from the designer's toolkit to integrate the needs of people, the possibilities of technology, and the requirements for business success*"[2], not necessarily in a specific order. Indeed, design thinking can support the new product development processes (Cocchi, Dosi, and Vignoli, 2021) by enabling iterations (Beverland, Wilner, and Micheli, 2015), user involvement (Brown, 2009), and abductive reasoning (Martin, 2010), which are all useful attributes (Micheli et al., 2019) to iteratively solve a problem that requires finding new opportunities based on a given technology and designing new innovative concepts.

Given that scant research has investigated this perspective on design thinking, we aim to answer the following research question: how might we leverage design thinking to find and design a suitable technology application?

3 METHODOLOGY

As a first step, we selected a representative organization to conduct our research (Siggelkow, 2007). Given our focus on design thinking, we selected an organization that uses design thinking as its primary methodology to conduct innovation projects and that also tackles technology-driven challenges aiming to find and design new applications for a given technology. The selected company is Oper.Space, which is the Design Factory for Open Innovation of the University of Bologna. In 2022, Oper.Space conducted 206 projects using design thinking to design new solution concepts for firms that operate in a wide range of industries, from automotive to food and beverage. Additionally, Oper.Space has been working on technology-driven projects for the past 8 years to find new opportunities and design new solution concepts based on emerging technologies, both with research centers, institutions, and companies.

In this context, we decided to adopt an Action Innovation Management Research (AIM-R) framework (Guertler, Kriz, and Sick, 2020) to tackle our research question. Indeed, this framework provides a structured research process for co-creating a solution to a problem, while also facilitating reflection on the knowledge gained during the research. Additionally, the AIM-R framework is conducive to achieving practical outcomes such as the development of programs (Mincolelli et al., 2020) and the launch of solutions resulting from those programs (Dosi, Cocchi, and Vignoli, 2021). The AIM-R models the research around five main phases: (1) analysis and framing, to investigate research gaps and practical problems; (2) project planning, to define both research questions and project design and planning; (3) execution on action, to execute the innovation project using research and working methods; (4) reflection and learning, to stimulate reflections of project and outcomes; and (5) communication and pivoting, to make systematic adjustments to overarching research plan.

According to the AIM-R phases, we started a co-design process with 2 highly experienced product-service-system designers, who had possessed over five years of experience in design thinking projects at Oper.Space. Together, we developed a program referred to as "*Tech to Market*". We developed the program in 5 iterations.

[2] Tim Brown. Design thinking defined

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3.1 The first version of Tech to Market

As a first step, in line with our research question, we defined the requirements of the program, which included using the design thinking approach to find new opportunities and design new solution concepts for a given technology. In this initial step, we also defined the criteria to assess at the end of the program its effectiveness, which included (1) the finding perspective, namely the extent to which the design team was able to explore and identify new, innovative, and feasible opportunities for the technology, and (2) the designing perspective, namely the extent to which the design team was able to design a solution concept for the technology (a concept of product, service, or product-service system) that was feasible, desirable, and viable.

Next, we co-designed with Oper.Space the first version of Tech to Market, drawing on our research experience in the field of design thinking and the experience of Oper.Space in design thinking projects. We analyzed 50 NPD projects conducted by Oper.Space, studying 50 mid-term and 50 final project presentations, and mapped all the design thinking tools used in these projects. Among these projects, 10 focused on a technology and Oper.Space employed a classical design thinking process to tackle them. Despite the senior designers involved finding the final solution concepts resulting from the process interesting, these solutions did not involve the starting technology, creating frustration within the design team and the involved company. Based on these analyses, we designed the first sequence of tools and process stages to be used in Tech to Market. This first release was composed of 2 main stages: opportunities identification and concept design. In the opportunities identification stage the design team was supposed to identify opportunities based on both the technology and the user needs, while in the concept design stage the design team was supposed to design the final solution concept.

We then engaged Poggipolini, an SME leader in the hot forging of critical and standard bolts in titanium and special steel alloys in highly complex mechanical parts. We defined with this company a technology-driven project, which aimed at finding new applications for the technology of "*smart bolts*" and designing the new product-service experience, and implemented the first version of the Tech to Market program to address the challenge. The program lasted 9 months, from October 2018 to June 2019, and involved three main actors: (1) the "*design team*", comprised of 6 MSc students with an interdisciplinary background and experience in design thinking practices; (2) the "*innovation coach*", a research fellow from Oper.Space with 3 years of experience in design thinking projects who supervised and coordinated the design team's activities; (3) and the "*company executive*", in this case the CEO of Poggipolini who provided strategic and technical support to the design team and facilitated decision-making activities.

To reflect and learn from the program, we conducted interviews with all program participants. We interviewed each member of the design team (6 interviews), to evaluate their level of understanding regarding the process and tools employed and to determine whether they required additional support from the innovation coach regarding specific tools. Additionally, we conducted 2 interviews with the innovation coach to understand the extent to which the design team was able to follow the process and tools provided and the modifications necessary to improve the effectiveness of the program. Finally, we conducted 2 interviews with the company executive to assess the program's results from the firm's perspective. Additionally, to guarantee proximity to the field and understand practices as they happen (Schatzki, 2005), we observed the evolution of the program by attending the mid-term and final presentations and triangulated the documentation produced by the design team with the presented results (Jick, 1979). At the end of the program, we held a 1-hour meeting with the innovation coach and a 30-minute meeting with the company executive to discuss the strengths and weaknesses of the program.

Based on the analysis of the interviews, observations, and meetings, we assessed the effectiveness of the program. We evaluated the finding perspective partially successful as the design team was able to identify feasible scenarios for the technology adoption but none of them was considered novel or innovative enough according to the company executive. Additionally, we positively evaluated the designing perspective as the proposed solution concept was feasible, desirable, and viable according to the company executive, who decided to open the project in the company's innovation pipeline.

In light of these evaluations, we co-designed with Oper.Space a new release of the program based on what was successful, partially successful, and unsuccessful for both the finding and designing perspectives. The subsequent program release entailed not only rearranging the order of the design thinking tools implemented throughout the process, but also selecting the most appropriate divergent and convergent phases of the process to apply them, incorporating new tools as needed to assist the design team during a particular phase, and removing tools that were considered to be unhelpful.

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3.2 Iterations to refine Tech to Market

After the completion of the first Tech to Market program, we proceeded to conduct an additional four iterations of the program. (Figure 1).

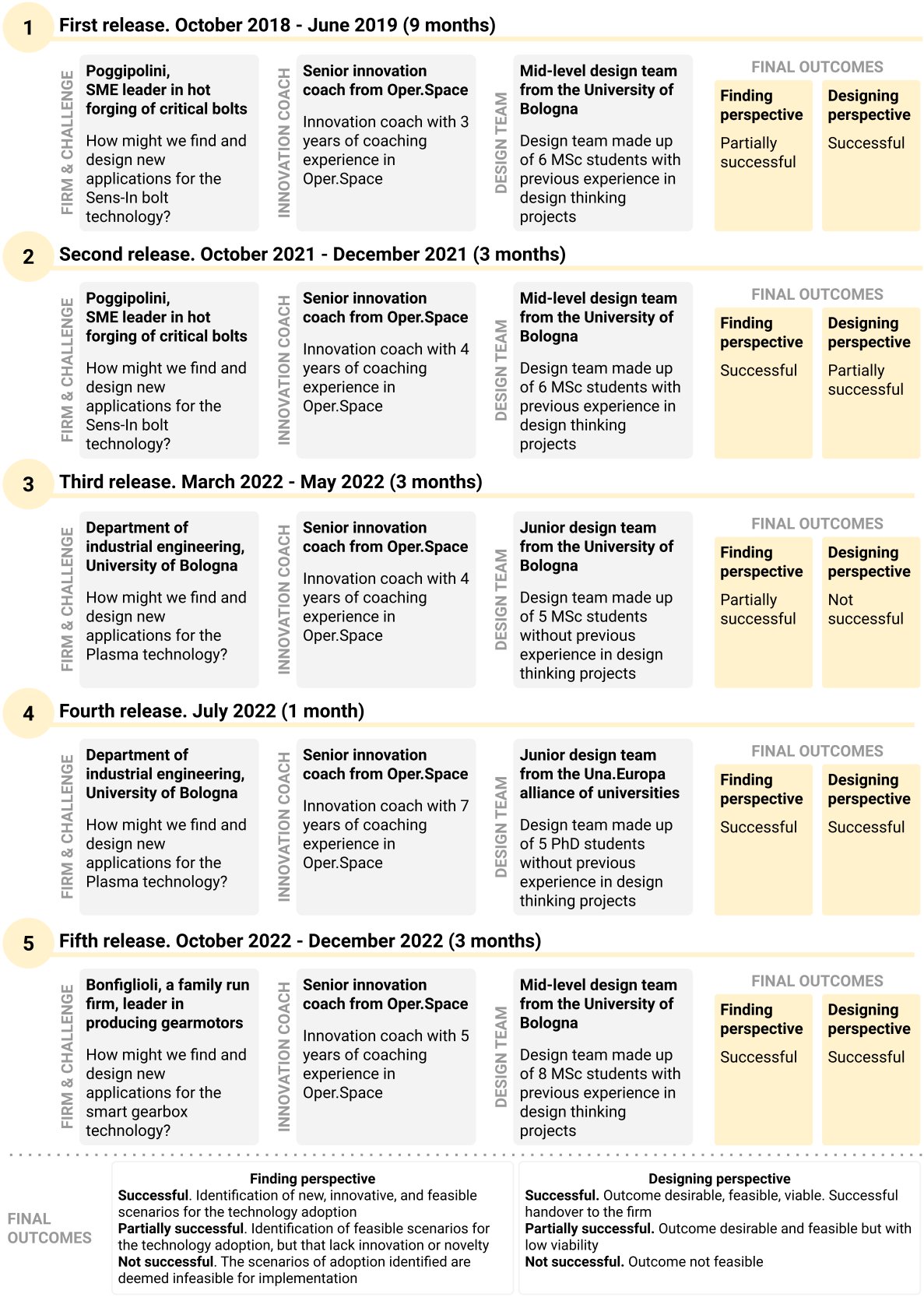

Figure 1. Releases of the Tech to Market program

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We conducted all the releases as we did for the first program implementation: we defined with a partner organization a challenge aimed at finding and designing new applications for a given technology; we implemented the newly designed program release; we performed interviews with all the relevant actors involved in the release; we observed the outcomes of the process by attending the mid-term and final presentations; and we held meetings with all the actors involved at the end of the program. In total, we conducted 52 interviews with the stakeholders involved, as detailed in Table 1, attended 5 mid-term and 5 final presentations, and held 5 meetings with the company executives and 5 meetings with the innovation coaches. Based on the analysis of the interviews, observations, and meetings, we assessed at the end of each release the effectiveness of the program and designed the subsequent iteration based on what was successful, partially successful, and unsuccessful for both the finding and designing perspectives. We stopped at the 5th iteration, since we felt we achieved saturation.

Table 1. Interviews

Program release	Stakeholder	Number of interviews
Release 1	Design team	6 (1 with each member)
	Innovation coach	2
	Company executive (CEO of Poggipolini)	2
Release 2	Design team	6 (1 with each member)
	Innovation coach	2
	Company executive (CEO of Poggipolini)	2
Release 3	Design team	5 (1 with each member)
	Innovation coach	3
	Company executive (Lecturer of the course of plasma industrial applications)	2
Release 4	Design team	5 (1 with each member)
	Innovation coach	3
	Company executive (Lecturer of the course of plasma industrial applications)	2
Release 5	Design team	8 (1 with each member)
	Innovation coach	2
	Company executive (Managing and technical director of mechatronic systems business unit)	2
Total		52 interviews

4 RESULTS

In this section, we present the results of our research which show how design teams might find and design a suitable application for a given technology by using and applying design thinking through the Tech to Market process. We also report some challenges still open related to the process and possible corrective actions to overcome the identified drawbacks.

4.1 Tech to Market

Tech to Market is a process that aims to bring a novel technology to the market by looking at new potential fields of applications and users. It leverages a design thinking approach to integrate the possibilities of technology with the needs of people, and the requirements for business success. Starting with an examination of the potential fields of applications of a given technology, the process facilitates the identification of target user groups, enabling the identification of relevant needs and problems to be addressed through the introduction of the technology within the intended field. The process is divided into three main stages: opportunities identification (i.e., finding a suitable application), user research, and solution concept design (i.e., designing a suitable application). Each of these stages is made up of a divergent and convergent phase. Figure 2 reports the structure of the Tech to Market process. In the appendix, we reported a synthesis of the adopted process for finding and designing new applications for "*smart bolts*", detailing its practical application and the outcomes achieved at each stage.

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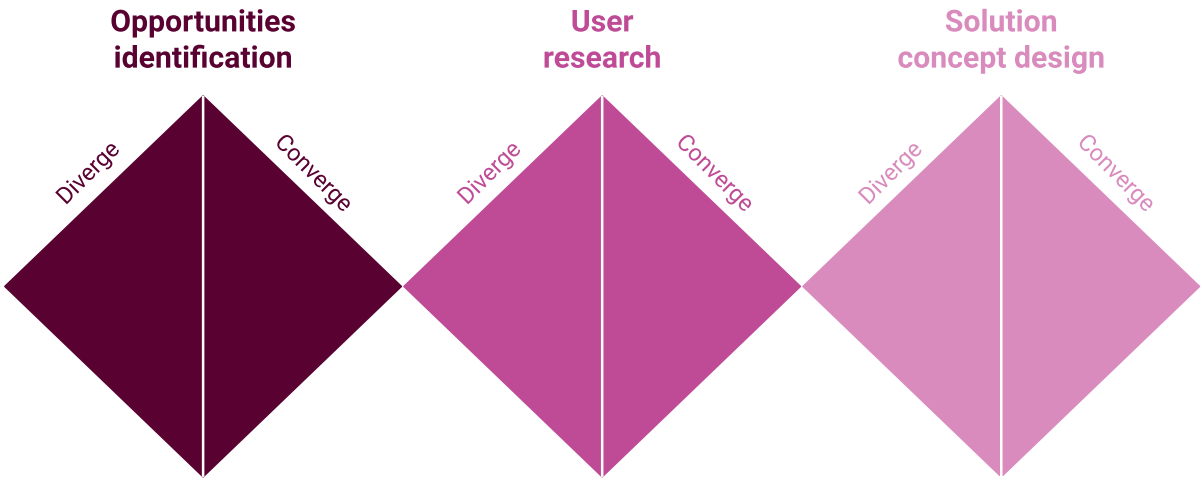

Figure 2. Tech to Market process structure

4.1.1 Opportunities identification (feasibility lens)

Tech to Market starts from a challenge based on a novel technology. It is based on an initial exploration of the technology to understand and generate the widest range of potential applications of the technology. The underlying assumption is that the greater the number of potential fields of application identified, the greater the likelihood of finding a good one. Tech to Market suggests exploring broad perspectives in terms of opportunities and leverages the propensity of designers to look laterally at reality and explore unconventional alternatives. To do so, Tech to Market relies on research tools such as desk research, mind mapping, benchmarking, functional analysis, and expert interviews. Desk research involves looking everywhere to learn and inspire ideas related to the technology and it is used to expand the initial knowledge of the team related to the technology as well as to spur a mind map. Mind mapping serves as a vehicle to unpack the technology into smaller topics, analyze them separately and build a shared framework around the technology. For each subtopic of the mind map, the design team runs benchmarking research by looking at direct and indirect competitors (e.g., competitors map), non-competitors' businesses (e.g., startups, cases from other industries and disciplines), and the world in general (e.g., PESTLE analysis). Functional analysis is here leveraged as a method for abstracting and describing the functions of the technology (Bonaccorsi and Fantoni, 2007; Balboni et al., 2021) and hypothesizing new fields of application based on the identified functions. Beyond being a divergent tool, expert interviews are also the first tool used to converge. Indeed, by involving contextual and technological experts in the process, the design team on the one hand can test the applicability of the technology in the fields of application proposed and, on the other hand, can open new possibilities based on the experience of the interviewee. All the evidence, problems, and opportunities identified from the research are then summarized into a frame that is used as an instrument of synthesis and selection of the most appropriate opportunity area. Visualization is a key element in this process phase, as it allows sharing of knowledge and discovery opportunities that may lead to innovative solutions.

4.1.2 User research (desirability lens)

Once high potential fields of application of the technology have been defined, the process involves a stage of user research which is based on the understanding of users' needs, problems, and desires through ethnographic research. This stage aims to identify which users' problems can be solved by introducing the technology. The stage of user research is usually the starting point of every design thinking project. The main difference that arises by moving this stage forward in the process is that the process is more constrained: given that a specific opportunity area has been already picked up, the space to explore users' behaviour is limited to the boundaries that the opportunity area involves. In this stage, Tech to Market entails classical design thinking tools such as ethnographic interviews, observations, personas, and “how might we” questions. The divergent phase of Tech to Market includes stakeholder mapping to represent all the various actors involved in the selected field of application and it starts from going out and performing ethnographic interviews and observations with those actors. The convergent phase involves personas and “how might we” questions to frame the problems and needs from the perspective of the people involved and inspire original solutions.

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4.1.3 Solution concept design (viability lens)

The final stage of Tech to Market entails the development of the solution concept along with its associated business model. This stage necessitates the use of ideation techniques commonly employed by design thinkers, such as brainstorming and the creation of rapid prototypes to render ideas tangible, elicit user feedback, and learn from failures. Experimentation is employed to validate or reject hypotheses pertaining to both the solution concept and its business model. By leveraging insights obtained from the testing of rapid prototypes, the design team incrementally advances toward defining the final solution concept and its corresponding business model.

Table 2. Tech to market toolkit

Stage	Phase	Example of tools
Opportunities identification	Diverge	Desk research, benchmarking, mind map, functional analysis
	Diverge/Converge	Interview with technological and contextual experts
	Converge	Evidence-Problem-Opportunity frame
User research	Diverge	Stakeholder mapping, Ethnographic interviews, Observations
	Converge	Personas, How might we questions
Solution concept design	Diverge	Brainstorming, Rapid prototyping
	Converge	Test of rapid prototyping, Business Model Canvas
We developed a "*miroboard*" that can be used as a guide for implementing the Tech to Market process. It is available open access at this **link**		

4.2 Open challenges and proposed actions to overcome them

We identified two main issues that those organizations willing to replicate Tech to Market must take care of. The first one concerns finding a way to embed some desirability analysis also in the first stage of the process. Indeed, although the first phase of Tech to Market mainly focuses on feasibility, to proceed with the second stage of user research it is essential to converge on those opportunities that can be beneficial for the final user. As the innovation coach involved in the second release of the program reported: "*The handover between the first and second stage of the process is crucial. Design teams might be tempted to focus on highly complex technical domains because they represent a huge opportunity. However, in these cases, they struggle to proceed because they do not have the competencies and skills to solve such complex technical issues. As a result, they spend a lot of time designing the feasibility of the solution, and do not focus on the desirability because the extent to which their solution concept will be good mainly depends on solving a technical problem*". He then added: "*Teams should start thinking of those actors who might benefit from the introduction of the technology and how the technology could enhance their current experience also in the first stage*". To reach this goal, we suggest performing a map of the actors involved in the feasible fields of application and developing a rapid prototype based on the technology that might be helpful for these actors during the convergent phase of the opportunities identification stage. The second challenge reflects a cognitive bias that may rise in the design team. Indeed, the design team might take the technology feasibility for granted and focus just on the desirability and viability domain in the second and third stages of the process. Yet, because of the flexibility of the process, the final product specifications might no longer be feasible. As the innovation coach involved in the fourth release stated: "*The fact that design teams converge on feasible opportunities does not imply that they are done with feasibility analysis. They have to work on feasibility issues also later in the process, even if it is not the main focus of those phases*". To prevent this issue and ensure the feasibility of the final product specifications, we recommend keeping the technological and contextual experts engaged throughout the process.

5 DISCUSSIONS AND CONCLUSIONS

Our results demonstrate the effectiveness of the design thinking approach in identifying and exploring new opportunities for a given technology, as well as in designing feasible, desirable, and viable solution concepts for the technology. Despite these successes, we also identified some challenges that remain unresolved for which we proposed potential corrective actions, thus contributing to the ongoing conversation about the implementation of design thinking in technology-driven contexts (Mahmoud-Jouini, Fixson, and Boulet, 2019). Our findings also carry practical implications, as they offer design teams a structured approach to identifying and defining appropriate applications for

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specific technologies using design thinking. While our research has shown how design thinking can be applied to identify and design a suitable technology application, it would be premature to conclude that the Tech to Market process can be equated with a standard design thinking process. In the present study, our focus has been on design thinking, as it facilitates iterations, user involvement, and abductive reasoning during development (Cocchi, Dosi, & Vignoli, 2021). Nevertheless, we have not explored the presence of other relevant design thinking attributes within the Tech to Market process, such as creativity and innovation, problem solving, interdisciplinary collaboration, ability to visualize, tolerance of ambiguity and failure, and blending rationality and intuition (Micheli et al., 2019). Future research might examine the extent to which Tech to Market can be compared to a standard design thinking process, and thereby deepen our understanding of what design thinking is - or is not - about.

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APPENDIX

We report as a reference for readers a synthesis of the process for finding and designing new applications for "*smart bolts*".

Context and challenge. Poggipolini S.p.A. created a startup, called Sens-In, for the development and commercialization of "*smart bolts*", namely intelligent fasteners able to communicate in real-time their status or a warning. In 2018, many industries were using the smart bolt, but Sens-In wanted to expand its market and find other fields of application and users.

Stage 1 - Opportunities identification. The design team identified 3 main fields of application for the Sens-In technology: infrastructures (e.g., control the status of amusement parks), biomedicine (e.g., control the status of plates), and energy (e.g., monitor residual torque force and stem deformation within bolts in a flange connection). The design team reported all the evidence, problems, and opportunities identified and the potential impact of smart bolts in these fields from the perspective of users. The design team in collaboration with the firm selected amusement parks as the most promising field of application.

Stage 2 - User research. The design team set up the problem from the perspective of the actor doing maintenance in amusement parks. Ben, a roller coaster technician, has to manually check all the bolts and write down all the information gathered in a report. Ben relies on his sight, hearing, and touch to make inspections. What if Ben could do maintenance with a tablet by looking at real-time data detected by Sens-In bolts? Unlike a solution based on human senses, a data-driven solution might help Ben do inspections, fill in reports, and provide much more certainty to the amusement park manager.

Stage 3 - Solution concept design. The design team designed the solution concept and the business model of the product-service system based on Sens-In bolts (see all the details on the SUGAR webpage[3])

[3] Sugar. Digital Mechadigital Solutions

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