t. XXVI, nr 1/2019 DOI 10.33226/1231-7853.2019.1.3

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New Product Development in high-tech startups — a conceptual framework

Rozwój nowych produktów w startupach technologicznych — przegląd koncepcji

New product development (NPD) is a key value creating process in a high-tech startup. This article discusses the relevance of the traditional approaches to NPD and assesses their applicability to a newly founded high-tech-venture. Further, recent concepts to innovative venture creation were reviewed: design thinking, lean startup and agile project management. Based on the analysis an integrated framework for high-tech startup NPD has been proposed. This study is based on an extensive literature review and systematic comparison of the concepts discussed in the current entrepreneurship, new product development and project management literature.

Keywords
New product development, high-tech startups, design thinking, lean startup, agile project management

Rozwój nowych produktów (NPD) to kluczowy proces tworzenia wartości w startupach technologicznych. W artykule omówiono znaczenie tradycyjnych podejść do rozwoju nowych produktów i oceniono je pod kątem przydatności dla nowo utworzonych startupów technologicznych. Ponadto dokonano przeglądu innych koncepcji innowacji i tworzenia nowych przedsięwzięć: podejścia projektowego, lean startupu oraz zwinnego zarządzania projektami. Na podstawie analizy zaproponowano zintegrowane podejście do rozwoju nowych produktów, które może mieć zastosowanie w kontekście startupów technologicznych. Artykuł ma charakter przeglądowy i powstał na podstawie analizy oraz systematycznego porównania najnowszych koncepcji dyskutowanych w literaturze przedmiotu. Opracowanie integruje wątki dyskusji z dziedziny przedsiębiorczości, rozwoju nowych produktów i zarządzania projektami.

Słowa kluczowe
Rozwój nowych produktów, startupy technologiczne, podejście projektowe, lean startup, zwinne zarządzanie projektami

JEL: M13; O32

Introduction

High technology startups are held to be important drivers of innovation and economic growth (e.g: Spencer & Kirchhoff, 2006). Development of a new product or service and launching it on the market is the key value creating process for a high technology startup (Ries, 2011; York & Danes, 2014). Thus, from a managerial perspective, the effective design of the new product development process (NPD) has an important role for high-tech startup success.

In the early stages of the development a high-tech startup may be perceived as project. The entrepreneur is aiming at development of an "*unique*" service or product. There is a constant need of "*managing constraints*" — time, resources, both financial and human, are scarce. Given the startup dynamics and high mortality rate, a new venture may have a *temporary character* (Ries, 2011). Thus, a newly founded startup has key project characteristics and can benefit from project-based approach to NPD (Project Management Institute, 2017).

In the literature there are mixed findings on whether project management is an appropriate method for managing innovative endeavors. On the one hand, project management may support the operational execution of tasks by providing more structure — thus, preventing chaos and disorganization. Several studies confirm that project management methods have a positive impact on new venture performance (e.g.: Dean, 1996; Murphy & Ledwith, 2007). On the other

hand, however, there are studies asserting that project management format lost its relevance for management of innovative projects, especially for radical innovations with high level of uncertainty and many question marks regarding both the customer, the product and the market (Shenhar & Dvir, 2007; Lenfle, 2008; Jetter et al., 2016).

The effectuation theory of entrepreneurship emphasizes the role of effectual thinking for the creation of new ventures (Sarasvathy, 2001). Yet, traditional project management approach for NPD requires mostly causal logic of planning, preparation of product specification, to move product implementation forward. On the one hand, in a new venture there is a need for experimentation and creative thinking (effectuation); on the other hand discipline, planning and execution is important to provide "realistic shape" to entrepreneurial dreams (causation). Thus, the question is how might we adjust the project-based approach to NPD to meet high-technology startup needs? This goal of this article is to review the relevant concepts on project management for NPD, discuss their assumptions and propose a conceptual framework for the management of high-tech startup NPD.

This paper is organized as follows: First, the theoretical concepts are outlined as well as the method of the inquiry. Then, major principles of design thinking, lean startup and agile project management in the context of high-tech NPD are discussed, compared and integrated to an integrated framework. The findings are summarized as well as directions for further research.

Theoretical foundation

Defining a high-tech startup

There is a variety of definitions of a startup company; e.g. Blank and Dorf (2012) define startup as "*a temporary organization occupied with search for a scalable, repeatable and profitable business model*". Ries (2011) describes startup as: "*an institution created to develop new products or services under conditions of extreme uncertainty*". The definitions are quite broad, but emphasize key features of a startup: 1) dynamic character described as a "search" for a business model, 2) development of a new product or service; for high-tech ventures this product can be classified to the high-tech or medium high-tech sector (Smith, 2005), 3) the need of working under conditions of "extreme uncertainty" — some authors even describe this environment as "unforeseeable uncertainty" (Sommer et al., 2009).

In the literature we can find also other criteria for distinguishing a "startup" from other types of firms: high growth potential, scalable business model, innovative products, above-average expenditures for research and development activities, no geographic restrictions, exploitation of market opportunities, a high share of external financing (Rostek & Skala, 2017).

NPD framework and its developments

The relation between project management and new product development in large corporate context is well established and relates mostly to the Stage-Gate® model (SG) and fuzzy front end literature (FFE). SG approach was developed by R.G Cooper in the late 80th as a framework for new product development in a corporate context. The process of NPD in this model is divided into distinct stages or phases, separated by decision points (described as gates) (e.g. Cooper et al. 1990; 1994; 2008). Problems of fuzzy front end (FFE) relate to the messy "getting started" period of new product development. In relation with SG, FFE embrace pre-development stage of innovation: the period between when an opportunity for a new product is first considered, and when the product idea is judged ready to enter "formal" development (e.g. Ried & De Brentani, 2004). In the recent developments of the SG concept R.G. Cooper (2014) proposes more accelerated, agile and lean approach to NPD. There are also studies confirming that lean SG approaches deliver the best performance in the context of SMEs (Leithold et al., 2015).

Both areas of research, SG and FFE, are discussed mostly in the context of large corporations. However the problems of "searching" for an idea (FFE) as well as organizing work on NPD along the product development cycle (SG) are relevant also for high-tech startups. New ventures are also confronted with the need to find a profitable product-market fit, implement the invention and finally commercialize it. But they operate in a more extreme environment than large corporations do. The question is whether in the highly uncertain and dynamic environment of a high-tech startup, established methods of managing NPD projects are helpful?

Applicability of the traditional NPD for high-tech startup context

High-tech-startups operate in a high uncertain environment and are usually not able to define the final product and target market upfront. They are rather searching for a profitable product-market fit, profitable business model and explore

opportunities (Ries, 2011). In the recent project management literature there are studies on the limited relevance of the traditional, phased approaches in the innovative context of NPD (Pons 2008; Lenfle 2008; Lenfle & Loch, 2010, Jetter et al. 2016). Some authors even claim, that the traditional format of project management lost its relevance for exploration projects (e.g. Lenfle 2008; Lenfle & Loch, 2010). Pons (2008) asserts for example that traditional project management approaches do not sufficiently take into account the marketing and commercialization phase of the NPD process as well as the need to constantly collect information from the market. The Stage-Gate process is designed mostly to limit risk, which is not always optimal when searching for radical innovations. In the process of innovative NPD work often repeats, partial solutions are developed and there is need of returning to a design phase.

Eppinger (2001) stresses that the complexity of NPD projects, as well as the dynamics of changes, require tools based on information flow, learning and gathering feedback. These practices are more adequate than stiff, pre-defined procedures. Shenar and Dvir (2007) argue that many projects nowadays fail, because organizations do not adjust the methods to the specific requirements of a particular project. They emphasize that in an innovative context adaptive (agile) project management approaches are better suited. Thus, before selecting adequate practices a project needs to be assessed according to its novelty, technology, complexity and pace.

Interesting inspirations emerge from the software engineering literature, where researchers provide evidence on benefits of combining agile project management with Stage-Gate process (Conforto et al., 2016) or embedding agile into predevelopment stage of innovation (Gonzalez, 2014). Empirical studies, however, discussing how high-tech startups design the process of NPD are scarce. In search for a suitable framework there is a need for more integration of the entrepreneurship, project management and NPD literature (e.g. Burganza et al., 2010; Fredriksen & Brem, 2017; York & Danes, 2014). The present study contributes to this discussion by proposing a conceptual framework for NPD, which may be applicable in the context of high-tech startups.

Method

This study has a narrative character. It is based on an extensive literature review at the intersection of project management, new product development and entrepreneurship. In addition it reviews and systematically compares new NPD approaches discussed in the recent literature. Firstly, concepts related to NPD were reviewed: customer development, lean startup, Stage-Gate approach, agile project management and SCRUM (Blank, 2007; Ries, 2011; Cooper, 1990; 1994; 2008; Highsmith, 2009). Then the concepts were systematically analyzed for their basic assumptions, compared in the light of the major the high-tech startup challenges. Finally findings were synthesized into a conceptual framework, which may be applicable for NPD in high-tech startups context.

Findings & Discussion

How do I find an idea? Design thinking in NPD

A the initial stage of a startup development the entrepreneur is searching for a promising business opportunity (Casson & Wadenson 2007). The key problem here is often related to the issue of uncovering of customer's hidden ('lateral') needs or identification a complex problem observable in the environment, for which none of the solutions has been found yet. The problem itself may be not well understood and described. From the perspective of NPD literature we have here a classical issue related to the fuzzy front end (FFE) of innovation on what would be the best idea to pursue into product development (e.g. Reid & De Brentani, 2004).

Design thinking (DT), recently gaining popularity as an approach to pre-development stage of innovation, may offer an interesting advise at the initial stage of a high-tech startup creation. Design Management Institute, a leading association of design practitioners working in business, defines this approach as: "*a human centered innovation process that emphasizes observation, collaboration, fast learning, visualization of ideas, rapid concept prototyping, and concurrent business analysis*" (Lockwood, 2009). While design thinking is a relatively new addition to the management literature, product design has been of keen interest to business researchers for more than a decade (Bloch, 2011), and the design process has long been explored by theorists in schools of architecture and design (Liedtka, 2015).

Design thinking differs from the traditional formal-analytical methods of problem solving by the mode of thinking applied in the process. Traditional formal-analytical methods are based on analytical thinking (deductive or inductive) as a common patterns of problem solving. The problem is outlined first and solution found based on logical reasoning. DT approaches, on the

contrary, involve *abductive thinking* in solving complex problems. The concept of abductive thinking, was developed by the philosopher Ch. S. Pierce, based on the assumption that no new idea can arise using deductive or inductive reasoning that uses data from the past. Abductive thinking in the process of a creative problem solving allows for exploration of alternative solutions, building connections between seemingly mismatched elements, obtaining insights and identification of patterns in the collected data. Abductive thinking combined with intensive research and synthesis of observations is the essence of design approaches used in creative problem solving (Martin, 2009). As some authors stress it: design process has both analytic and synthetic elements, and it operates in both the theoretical and practical realms (Beckman & Barry 2007).

The main principles of the DT approach include: 1) *Exploration and iteration*: In contrast to analytical approaches, DT assumes that at the beginning the problem solving process the problem and purpose are not completely described and defined. Only in the process of trying out and testing of the solutions it becomes more clear, what should and can be done, 2) *Concentration on the user*: the key criterion for success is to uncover and solve user's problem, satisfy its lateral needs or improve experience that the user has with the product or service. Therefore, the DT process has mainly a human focus and emphasizes the interdisciplinary team work that brings different views on the user and its needs. In the discovery process a wide range of qualitative and quantitative methods are applied to obtain data about the user as well as their reflections on the experience with a product, 3) *Visualization, experiments and prototyping*: DT emphasizes the importance of developing and testing prototypes and physical artifacts. The user can experience the mock-up version of the product or service at an early stage of the solution generation process and provide feedback. Visualizations and prototypes evoke direct emotional engagement and provide a good forecast of how the later service or product will be perceived by the user. The process of experimentation with prototypes can be characterized as a process of constantly going back and forth between the different human and nonhuman actors, 4) *Observation and understanding*. Understanding the user and his "latent needs" requires intensive observation in real life and work situations. Immersing with the user's world and empathizing allows for understanding the motives of action and uncovers needs that the user himself might be not aware of (Gartner & Ludwig, 2015; Liedtka, 2015).

In the literature and practice there are various process models of the DT approach (e.g. Model IDEO, Hasso Plattner, Model Design Council, IBM). Most of these models describe the process as a '*system of overlapping spaces*'. The notion of 'iteration' is a as key characteristic of this process. The assumption is that premature decision on one idea needs to be avoided; only at a later stage, ideas should also be evaluated for technological feasibility and business justification. Those that pass the next two assessments positively can be taken into account for the further NPD process: implementation and commercialization.

DT approach may have interesting application for building a high-tech ventures. We can observe that the logic of convergent thinking resembles the effectuation logic of exploring many possibilities. "Causation processes take a particular effect as given and focus on selecting between means to create that effect. Effectuation processes take a set of means as given and focus on selecting between possible effects that can be created with that set of means." (Sarasvathy, 2001, p. 245). Another important aspect is the discovery of the lateral customer needs. In the world of the abundance of technological solutions, spotting the "real customer needs and wants" as starting from the human aspect of a product, not from technology as "solution" may be a better recipe for success. Previous studies emphasized also that by engaging user in the innovation development some level of the fuzziness from the fuzzy front-end of innovation may be removed (Alam, 2006). Other authors emphasize that DT as a practice is valuable for improving innovation outcomes by helping decision-makers reduce their individual level cognitive biases about their product assumptions (Liedtka, 2014). A valuable achievement of design approaches is the development of a wide range of tools and techniques that can enrich work with innovations. They were taken from many fields of knowledge: art, engineering, anthropology, psychology, marketing, and others (Tschimmel, 2012).

How do I check that the idea is worth investing? — Lean startup in the NPD

The Lean Startup (TLS) is gaining popularity in the last decade as an modern approach to startup building. "*The Lean Startup is a set of practices for helping entrepreneurs increase their odds of building a successful startup*" (Ries 2015, p. 8). The concept itself is rooted in the customer development developed previously by of S. Blank (2007) as well as personal experience of the author E. Ries with startup creation. The logic of reasoning in TLS is inspired by "lean manufacturing" and concentrates on weeding out the waste often found in product and business development processes in startups (Fredirksen & Brem, 2017). E. Ries noticed that managers of

startups instead of actively looking for what brings value to the client, lose time and money to create things that nobody, or almost nobody, is interested in.

TLS method is based on a few basic assumptions that can also be found in the traditional lean manufacturing approaches: 1) *Avoiding waste* in the development process and focusing on the value in the product or service for which the customer will want to pay, 2) *Concentration on the customer* from the initial stage of business development. This is the opposite of traditional thinking, according to which the product is first developed and the verification process begins only after it has entered the market. Clients' feedback data are collected and analyzed, e.g. qualitative opinions and information on what customers do not like and how many people use the product and consider it valuable, 3) *Searching for a business model by experimenting*. The assumption of the method is that the startup founder does not start with a business plan, but searches for a profitable business model. It resembles the process of "tuning the engine of growth"; only after several quick rounds of experience and feedback entrepreneurs may discover the model they focus on, 4) *Validated learning cycle* that includes creating a product assumptions, measuring results, learning and adjusting the business model based on the collected customer response data. The assumption is that as long as the product does not really enter the market, it remains only a hypothesis that needs to be verified. Verification of hypotheses is carried on through experiments and knowledge of how to build a sustainable company appears as results of experimentation (Pease et al., 2014).

TLS method distinguishes two types of hypotheses: a hypothesis of the value that the product provides and a hypothesis of growth that tests how new clients learn about a product or service. The result of the development stage is a *minimal viable product* (MVP). It contains the minimum set of functions required to produce an economically viable and useful product. MVP is not the simplest or the cheapest version of the product, but a product that carries some value for both the company creating the product and its customers. Based on MVP previously adopted hypotheses of value and growth can be verified. Finally, based on data collected from customers, conclusions are drawn and the idea is modified, corrected or rejected. If repeated attempts at improving the key metrics fail, then the entrepreneur may have to *pivot* — which is a substantial change in the business model (Ries, 2011).

Fredriksen and Brem (2017) conducted review of the key concepts embedded in the lean startup method and found out that the majority of them is supported by the concepts already discussed in the academic literature such as: user and customer involvement, iterative NPD, experimentation in NPD, early prototyping for proof of business (MVP) and effectual thinking. The authors argue that key methods introduced in lean startup find substantial evidence for the efficacy in the scientific literature. Other studies emphasize that the continuous face-to-face customer contact and reliance on the "out of the building" work have the potential of eliminating some of the biases inherent in the innovation process (York & Danes, 2014).

In sum, it can be concluded that the lean startup approach can be perceived as an "end to end" approach to NPD in an entrepreneurial context. It helps organizations to manage NPD in an extremely uncertain environment by low cost prototyping, validated learning and face-to-face customer contacts. Compared with design thinking it is more focused on the commercial aspects of finding product-market fit than on the product usability.

How do I implement the idea? — Agile project management in NPD

Agile project management is rooted in the software development literature, therefore it has a particular importance for building high-tech startups, where in many cases the engine of the product is based on a functioning software. Since Agile Manifesto in 2001, the agile methods have significantly changed the approach to software development. Unlike traditional development methods characterized by sequential phases and heavy upfront planning, agile methods deal with unpredictability and change by relying on people and close customer collaboration rather than formalized processes. Today, many different agile methods are in use. During the last decade Scrum method has become well established in small-scale, as well as large-scale software development. Although the variations of agile methods differ in details and techniques, overall agile principles such as 'flexibility', 'working code' and 'customer collaboration' lie at the heart of all of them (Bosch et al., 2013). Conforto et al. (2016) conducted a bibliometric review of definitions and proposed the following: "Agility is the project team's ability to quickly change the project plan as a response to customer or stakeholders needs, market or technology demands in order to achieve better project and product performance in an innovative and dynamic project environment". Further, the researchers emphasized key major implications of agility for managing projects: 1) agility should be perceived as a team property, rather than just an adjective defining a set of methods and practices, 2) the effectiveness of the application can depend

on the co-play of several elements: teamwork, organization and project factors, 3) the level of agility can be measured by two main indicators: the speed of changes to the project plan and the activity of customer's involvement (Conforto et al., 2016).

In the context of innovative NPD Highsmith (2009) distinguishes the following principles of agile project management: continuous innovation — focusing on the continuous delivery of value to the customer; adaptability of the product — delivering value today with simultaneous consideration of product's ability to adapt to the needs of tomorrow; reduced delivery time, which allows to fit the market window of opportunity and improve return on investment (ROI); adapting people and processes — to respond to rapid changes related to the product and business, adaptive people behaviors as pre-requisite for adaptable processes; stable and predictable results — to support business growth and profitability.

The assumptions of Highsmith (2009) suggest that in managing exploration projects the measures of success should be based on: vision, cost and time. Vision means here concentration on a valuable product for the customer. Shenhar and Divr (2007) also propose moving from the traditional 'triple constraint' framework of time, scope, quality and budget, (Project Management Institute 2017) and propose shifting attention towards five dimensions of project success: 1) project effectiveness, which means meeting time and budget requirements, 2) impact on the customer: meeting the requirements and achieving customer satisfaction, as well as benefits and loyalty, 3) impact on the team: satisfaction, maintenance and personal growth, 4) business results: return on investment, market share and business growth, and finally an important factor for success is: 5) preparation for the future, which relates to new technologies, new markets and new capabilities.

One of the most popular method of agile project management nowadays is Scrum. Interestingly the method was initially inspired by an examination of new product development (NPD) (Schwaber, 1995). Lane et al. (2012) propose combination of six management characteristics, which results in an effective product development: built-in instability of the process, self-organizing project teams, overlapping development phases, "multi-learning", subtle control and organizational transfer of learning (Takeuchi & Nonaka, 1986). There is a variety of practices of Scrum, allowing to support the above principles of development; for example the concept of *product owner* and *product backlog* helps in prioritization and re-shifting of developments work according to the value for the customer. Organizing of development in "*timeboxes*" (*sprints*) helps to freeze chunks of work and focus the team on task realization for the next sprint, while still maintaining flexibility and readiness to changes. Scrum communication organized in *sprint planning meeting, sprint reviews, retrospective* allow for better self-organization of teams and exercising of subtle control mechanisms as well as organizational transfer of learning.

In sum, agile project management concentrates on iterative product releases and integrates change management into the NPD process thus pulling risk reduction earlier in product development. In the high-tech startup context it is a useful method especially for product implementation, particularly in software-based ventures. But also in hardware-based firms there is usually some part of a product, which requires software to be fully operational. Agile project management supports incremental product development, team collaboration, concentration on the value for the customer. Thus it is in line with the majority of work principles of lean startup and design thinking. The focus of the method is however more on the operational — engineering part of product implementation, but this method of development can be complementarily integrated into NPD cycle.

Conclusions

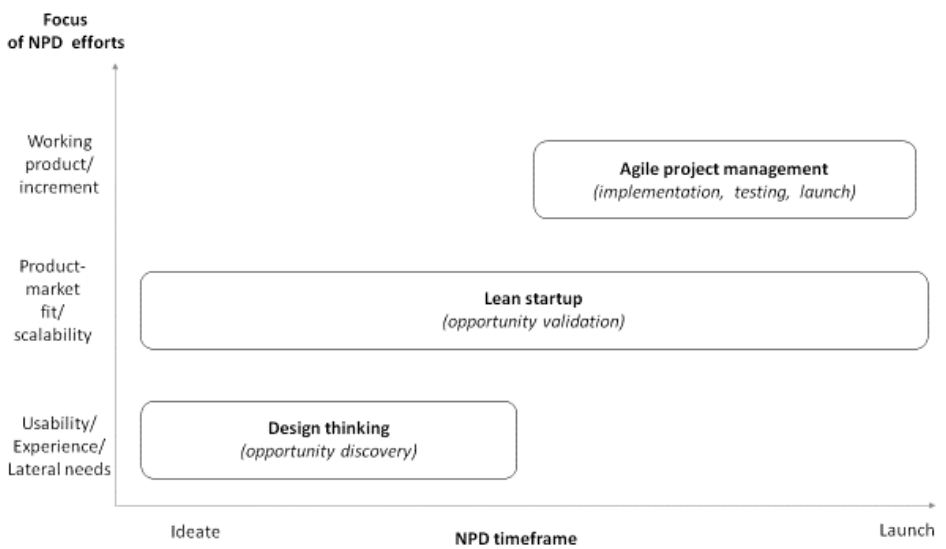
This article discussed the approaches to NPD in a high-tech startup context. Since high-tech startups operate in an environment of many "unknown unknowns" and are not able to describe the product or target customer segment upfront; the applicability of traditional, plan-based NPD formats is limited. Design thinking, lean startup and agile project management were discussed as possible methods to support NPD process in an innovative, high-tech startup context. The presented approaches have several common characteristics: they are iterative and based on a process, which can described as "a system of overlapping spaces". There is high emphasis on learning and experimenting as well as strong focus on the user/customer and its needs. Quick prototyping, working with product "mock-ups" is also a common feature of the discussed methods. There are, however, also some differences, which suggest that the approaches focus on solving different problems related to the NPD process. Table 1 summarizes key differences. Thus, it may be concluded that the presented methods are rather complementary and can be integrated along the NPD process. The proposed framework is outlined on the Figure 1.

Table 1. Distinctive characteristics of the discussed NPD approaches — comparison

Dimension	Design thinking	Lean startup	Agile project management
Entrepreneur's concern	How do I find a promising idea for a startup?	How do I know whether the idea is commercially feasible and scalable?	How do I develop the product, taking into account many expected changes underway?
Major issue	Discovery of a lateral user needs/ / user experience	Problems of Product — Market fit/ / Scalability potential	Embedding change into the software development process
Focus	User/ Human-centered	Customer/ Business-centered	Working Product/ Increment/ / Functionality-centered
"Stage" of NPD	Early (ideation)	Entire process "Idea to launch"	Implementation; Product testing; improvements and maintenance
Unique practice	Abductive thinking Convergent thinking	Minimal Viable Product Pivoting	Timeboxing Self-organization

S o u r c e: author's own elaboration.

Figure 1. Integrated NPD approach for high-tech startups



S o u r c e: author's own elaboration.

Limitations and areas for further studies

The present study has a narrative character and proposes integration of recently discussed, modern approaches to NPD into one conceptual framework applicable in a high-tech startups context. Based on the analysis of design thinking, lean startup and agile approaches as well as related academic literature several observations were drawn and summarized. The approaches are suitable for solving entrepreneur's concerns stemming from high uncertainty of NPD process and provide advantages over traditional approaches to NPD. The framework may be also applicable in the context of large corporations pursuing radical innovations or organizing cooperation with high-tech startups or sourcing innovative ideas as part of open innovation activities. However the validity of the proposed framework was not tested empirically. It can be the subject of further qualitative and quantitative studies. The article integrates project management, new product development and entrepreneurship perspectives and can be a good vantage point for further research at the intersection of this academic disciplines.

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