

DOKUZ EYLUL UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

**EFFECTS OF NEW COLLABORATION
ENVIRONMENTS ON R&D COLLABORATION
AND INNOVATION**

by

Elif Yağmur PETEKKAYA

September, 2024

İZMİR

EFFECTS OF NEW COLLABORATION ENVIRONMENTS ON R&D COLLABORATION AND INNOVATION

**A Thesis Submitted to the
Graduate School of Natural and Applied Sciences of Dokuz Eylül University
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by

Elif Yağmur PETEKKAYA

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İZMİR

THESIS EXAMINATION RESULT FORM

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EFFECTS OF NEW COLLABORATION ENVIRONMENTS ON R&D COLLABORATION AND INNOVATION

ABSTRACT

In recent years, the world has been faced with challenges such as the Covid pandemic, which continuously increases global competition and affects and alters direct business practices. The escalation of competition in the business world and the necessity to overcome challenges have mandated comprehensive research, multiple perspectives, the need for sufficient knowledge about various factors (such as technology and science), openness to new approaches, and collaboration. In order to overcome these challenges and sustain competition, new Research and Development (R&D) and Innovation approaches based on collaboration have begun to be sustained through different and advanced tools such as digital meeting platforms, virtual reality, and other virtual spaces and environments. This requires integrated knowledge sharing and collaboration from the initial concept of a product to its realization and marketing. In this study, collaboration-based R&D and Innovation tools and environments were investigated using keywords such as "Digital Collaboration Tools," "Online Collaboration Tool," "Online Innovation Management Software," "Innovation Digitalization Tool," "Collaborative Innovation Platforms", "Innovation Solution Software" and "Crowdsourcing Innovation Platforms" in the literature. The features they offer were classified, and those that could be used for collaborative innovation in R&D were identified, aiming to select the appropriate tool according to the users' needs.

Keywords: Collaborative Innovation, R&D collaboration, collaboration environments, digital collaboration tools

YENİ İŞBİRLİĞİ ORTAMLARININ AR-GE İŞBİRLİĞİ VE İNOVASYON ÜZERİNDEKİ ETKİLERİ

ÖZ

Son yıllarda dünya, sürekli artan küresel rekabet ve doğrudan iş yapış şekillerini etkileyen ve değiştiren Covid pandemisi gibi zorluklarla karşı karşıya kaldı. İş dünyasında rekabetin artması ve zorlukların üstesinden gelme ihtiyacı, kapsamlı araştırma, çoklu bakış açıları, birden fazla faktör hakkında yeterli bilgiye sahip olma gerekliliği (teknoloji ve bilim gibi), yeni yaklaşımlara açıklık ve iş birliğini zorunlu hale getirdi. Bu zorlukların üstesinden gelmek ve rekabeti sürdürmek için, iş birliğine dayalı yeni Ar-Ge ve İnovasyon yaklaşımları, dijital toplantı platformları, sanal gerçeklik, diğer sanal alanlar ve yerler gibi farklı ve gelişmiş araçlar aracılığıyla sürdürülmeye başlanmıştır. Bu da, ürünün ilk konseptinden başlayarak gerçekleşmesi ve pazarlanmasına kadar bütünleşik bir bilgi paylaşımı ve iş birliğini gerektirmiştir. Bu çalışmada, literatürde "Dijital İşbirliği Araçları," "Çevrimiçi İşbirliği Aracı," "Çevrimiçi İnovasyon Yönetim Yazılımı," "İnovasyon Dijitalleştirme Aracı," "İşbirlikçi İnovasyon Platformları," "İnovasyon Çözüm Yazılımı" ve "Crowdsourcing İnovasyon Platformları" gibi anahtar kelimeler kullanılarak işbirliği tabanlı Ar-Ge ve İnovasyon araçları ve ortamları araştırılmıştır. Bunların sunduğu özellikler sınıflandırılarak Ar-Ge'de işbirlikçi inovasyon için kullanılabilecek olanlar belirlendi ve kullanıcıların ihtiyaçlarına göre uygun aracın seçilebilmesi hedeflenmiştir.

Anahtar kelimeler: İşbirlikçi İnovasyon, arge işbirliği, yeni çalışma ortamları, dijital işbirliği araçları

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ABBREVIATIONS

R&D	: Research and Development
SME	:Small and Medium-sized Enterprises
ARAS	:Additive Ratio Assessment
IBM	:International Business Machines
KPI	:Key Performance Indicators
CWET	:Collaborative Working Environments and Tools
SW	:Software
MCDM	:Multi-Criteria Decision-Making
AHP	:Analytic Hierarchy Process
FT	:Feature
MATLAB	:MATrix LABoratory
AI:	Artificial Intelligence

LIST OF SYMBOLS

S_i :Sum of each row

S_0 :Sum of max of the each column

K_i : The degree of the degree of the target utility



CHAPTER ONE

INTRODUCTION

1.1 Context and Relevance of the Study

Innovation has long been recognized as a crucial process for businesses seeking to maintain competitiveness and adapt to evolving market demands. The capacity to innovate is essential for driving growth, enhancing operational efficiency, and meeting the changing needs of consumers. However, recent global events, such as unexpected pandemics and geopolitical conflicts, have disrupted traditional working patterns and exposed the limitations of conventional innovation processes. These disruptions have underscored the need for innovation processes to be resilient and adaptable, prompting firms to move beyond established methods and integrate new tools and approaches.

Historically, innovation processes have relied heavily on internal resources and face-to-face interactions among team members, with traditional models often centered around internal Research and Development (R&D) departments and conventional project management tools. However, the advent of digital technologies and the increasing frequency of global disruptions have necessitated a transition to more dynamic and flexible innovation processes. Organizations are now recognizing the imperative to incorporate external partners and resources to enhance their innovation capabilities. This shift involves not only the adoption of new tools but also a fundamental rethinking of how innovation is managed and executed within a collaborative environment.

Understanding this context is essential for comprehending the objectives of this thesis. The study is dedicated to examining collaborative tools and environments that have been developed to address the contemporary challenges in innovation management. By investigating how these tools and environments facilitate and enhance collaborative innovation, this research aims to offer valuable insights into their effectiveness and practical utility. The goal is to elucidate how these new solutions can contribute to overcoming current limitations in innovation processes and to improve organizational performance in a dynamic and rapidly evolving market.

1.2 Focus and Scope

This study specifically focuses on examining new tools and platforms that facilitate collaborative innovation. It explores how these tools can be utilized across various phases of the innovation process. The scope of the research includes evaluating collaborative tools and platforms that have emerged as significant advancements in the field of innovation management. By analyzing these tools and platforms, the study aims to assess their effectiveness in enhancing team productivity, improving communication, and facilitating seamless collaboration between internal and external stakeholders.

1.3 Relevance of the Research

The relevance of this research is underscored by the significant gaps identified in the existing literature regarding the integration and impact of novel collaborative tools within innovation processes, particularly in the context of R&D. While prior studies have explored various aspects of innovation management tools, including their effects on communication and their overall influence on the innovation processes within Small and Medium-sized Enterprises (SMEs), there remains a notable deficiency in the comprehensive analysis of contemporary collaborative tools and environments.

Existing research have predominantly focused on the rationale behind using certain tools, their general impact on communication. However, there is a conspicuous lack of detailed studies addressing the specific features of new collaborative tools and environments that are crucial for facilitating effective collaborative innovation. Notably, there has been no in-depth investigation into how these features influence user preferences and decision-making when selecting among various collaborative tools and environments. This gap presents a critical opportunity for further exploration.

In the context of this study, "collaborative innovation tools" refer to specialized applications or software designed to support different aspects of collaborative work and innovation processes. These tools are often tailored to specific tasks or functions, playing a crucial role within the broader framework of collaboration and innovation. Conversely, "collaborative innovation platforms/environments" denote structured,

often internet-based platforms where individuals and organizations converge to crowdsource innovative solutions and tackle innovation-related challenges through collective effort.

By addressing these gaps, this research aims to provide a detailed examination of contemporary collaborative tools and environments, exploring their functionalities and how they contribute to the collaborative innovation process. This includes an investigation into the features that may influence user choices when selecting these tools. Through this exploration, the study will contribute valuable insights into how organizations can effectively utilize these tools to enhance their innovation strategies and adapt to modern challenges.

The significance of this research is further amplified by the practical implications for firms striving to remain competitive in an increasingly complex and dynamic market environment. Understanding the specific features of collaborative tools and environments can aid organizations in selecting the most suitable solutions for their needs, thereby improving their innovation processes and overall performance.

This thesis is structured around three primary research questions that will guide the investigation into these novel tools and environments. By filling the existing research gaps and providing actionable insights, this study aims to offer a comprehensive understanding of how new collaborative tools and environments can be leveraged to improve innovation processes and address contemporary challenges in R&D.

1.4 Research Questions and Objectives

The primary objective of this study is to identify and evaluate new tools that enhance collaborative innovation processes. The research seeks to answer the following questions:

1. Research Question 1: What are the new platforms and tools for collaborative R&D and innovation?
2. Research Question 2: What are the features that might influence users while choosing collaborative tools and environments?
3. Research Question 3: Collaborative innovation software/platform selection.

This study is designed to address key questions given above regarding new tools and environments for collaborative R&D and innovation, the features influencing user choices, and the selection of the most effective collaborative innovation software. To answer Research Question 1, a comprehensive analysis of new collaborative innovation tools and environments is conducted through a systematic review of literature and practical applications. This involves searching academic databases and application review platforms to identify and categorize tools based on their relevance to different stages of the collaborative innovation process. For Research Question 2, the study examines the distinguishing features of these tools by reviewing software websites and consulting expert opinions, ensuring a detailed comparison and validation of features. Finally, Research Question 3 focuses on selecting the optimal collaborative innovation software or environment. This involves applying the Additive Ratio Assessment (ARAS) method, a multi-criteria decision-making technique, to evaluate and rank the alternatives based on their performance across various criteria.

1.5 Overview of the Structure

The thesis is structured to systematically address the research objectives and provide a coherent analysis of the findings. The first chapter offers an overview of the thesis.

The second chapter focuses on the evolution of innovation processes from historical to contemporary contexts, examines their characteristic features, and evaluates the advantages and challenges introduced by new approaches. It also reviews the tools utilized throughout different periods and their transformations over time.

The third chapter focus on the thesis research questions which are mentioned above and explained detailed methodology that is followed.

The fourth chapter presents the results of the study, addressing the research questions through a detailed analysis of the identified tools and platforms. This chapter provides a structured examination of how different tools perform across various innovation phases and offers insights into their effectiveness and utility in collaborative settings. This chapter also includes a case study to illustrate the selection

of tools that might be most advantageous for firms in real-world settings. It utilizes the ARAS method for evaluating and ranking alternatives based on multiple criteria.

The concluding chapter synthesizes the findings of the study, discusses their implications for firms, and suggests potential areas for future research. This final section aims to provide actionable insights and recommendations for organizations seeking to enhance their innovation processes through collaborative approaches. The chapter also highlights potential areas for future research, aiming to address existing gaps and contribute to ongoing advancements in the field.

Through this structured approach, the thesis aims to offer a comprehensive understanding of how new tools and methodologies can be leveraged to improve collaborative innovation processes and address current gaps in the literature.

CHAPTER TWO

BACKGROUND OF THE STUDY AND REVIEW OF THE LITERATURE

This section explores the evolution of innovation processes from historical to contemporary contexts, examines their characteristic features, and evaluates the advantages and challenges introduced by new approaches. It also reviews the tools utilized throughout different periods and their transformations over time.

2.1 Changes of Innovation Processes Over Time

Innovation is defined as the ability to transform an idea into a solution from the customer's perspective, thereby creating a product or service that adds value. (Gassmann and Enkel, 2004; Jacobs and Snijders, 2008; Drucker, 1985; Albury 2005). The innovation process fosters the growth of the organizations and provides an advantage for competitiveness. The period of the early 1950s and mid-1960s is referred to as the first generation of the innovation process. During this period, firms create prototypes of the product by combining science with engineering, and then these prototypes had been carried out to mass production. It was commonly believed that increased R&D efforts would lead to the emergence of more innovative products or services. During the mid-1960s and early 1970s, the market served as the primary source of ideas for guiding R&D activities. In this period, the supply-demand balance has been formed and the direction of demand has gained importance. With the onset of the 1970s, the foundations of the innovation model applied in its current sense were laid. The innovation process was characterized by stages that were functionally distinct yet interdependent and interactive. During this period, top management began to demonstrate a commitment to and visible support for innovation. In the early 1980s and 1990s, IT-based manufacturing equipment and tools started to be used. In this period, design for manufacturability was taken as the focus. In the 1990s, organizations began to give importance to time-cost trade-offs to keep their competitiveness. The form of innovation that we call “closed innovation”, in which firms or organizations could produce innovations as much as their own know-how and technology, was accepted in this years. Later on with the emergence of the open innovation phenomenon, it was accepted that innovation was not a feature that should be maintained and developed within the firm (Rottwell, 1994; Meissner, Kotsemir ,2016).

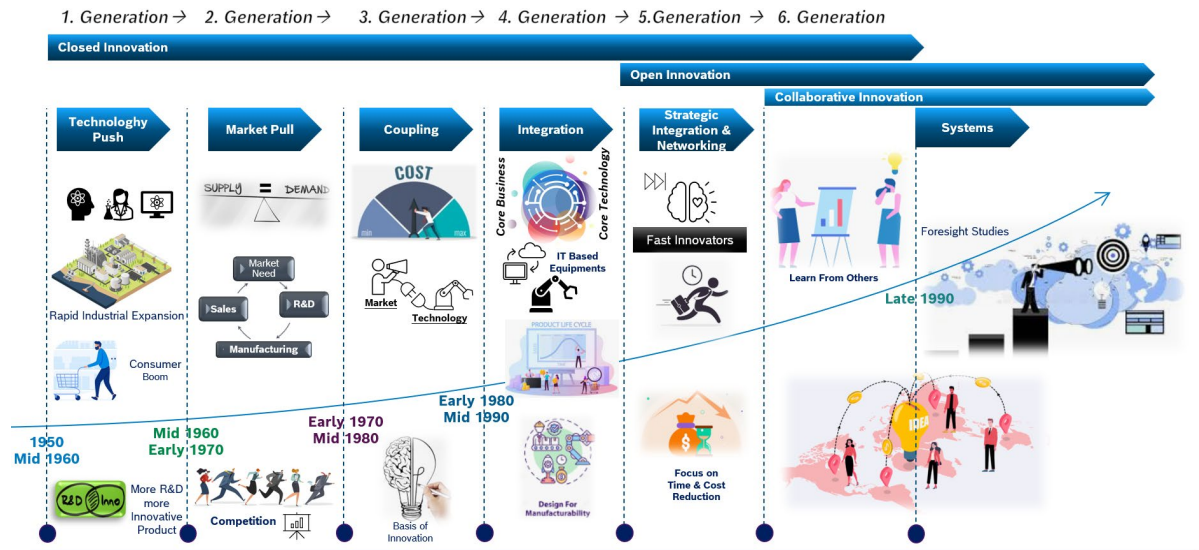


Figure 2.1 Changes of innovation processes over time

The concepts of closed innovation and open innovation will be discussed separately below.

2.2 Characteristics of Closed Innovation

A key feature of closed innovation is vertically integrated research and development within the firm. R&D activities are constrained by the firm's internal knowledge and technology. In closed innovation, firms are required to generate their own ideas, develop them, market and service the resulting products, finance the efforts, and independently manage all feedback and issues. (Chesbrough, 2003; Herzog, 2008). According to Chesbrough (2003), closed innovation was based on the phenomenon that "if you want something done right, you have to do it yourself" (p. 285). Since only internal resources are used in product or service development, know-how remains within the firm or organization.

We can list the unwritten implicit rules of closed innovation below:

- 1) Hire the most knowledgeable and intelligent employees; thus be the best.
- 2) If you want innovative products or services, you have to create them yourself.
- 3) The first founder of the innovative idea, the first gets the market.

4) More in house R&D leads to more new ideas and innovation.

5) The know-how and intellectual property need to be kept in-house not to lose competitiveness.

According to Chesbrough (2003), there were some challenges posed by closed innovation. The first, when an experienced employee who had worked for years left the firm, all the experience and knowledge need to be transferred to the new employee. The second factor was that with the capital support provided, highly talented new startups became competitive with large companies that devoted their years to R&D. Thirdly, with the increase in product and service diversity, the number of products marketed increased and this shortened the shelf life of the products. Thus, more firms have become competitors. Whilst industry was under the influence of these challenges, closed innovation was no longer an effective option.

For these reasons, a new approach, open innovation, has emerged over time.

2.3 Characteristics of Open Innovation

In time, innovations brought by technology had an important role in guiding today's society by altering the way individuals and organizations interact with each other (Orsoletta et al., 2022). The advancement of technology has enabled instant feedback and data collection from across the globe, leading to significant developments, particularly in the field of science (Zhang et al., 2015). This has increased transparency and facilitated the creation of broader and more diverse networks for generating and disseminating knowledge (Joseph and Davis, 2017). In response to the rising demand for research and external information sources, numerous online initiatives have been developed (Demeter, 2019). In the light of all these developments, the most important and popular concept of the 21st century was put forward by Chesbrough in 2003. Chesbrough wrote that innovation has shifted from closed to open (Dodgson, 2017). According to the phenomenon, firms should not only use their own internal resources but also external information and resources to bring their technologies or products to a better level (Chesbrough, 2003; West and Bogers, 2014). Therefore, the assumption of a firm and its R&D team was only or the best option for creating innovation was being abandoned.

In Table 2.1, differences between open and closed innovation are given. Whereas firms previously employed closed innovation strategies, resulting in a restricted allocation of resources and consequently limited product or service diversity, the adoption of open innovation methodologies has facilitated an expansion of diversity. Likewise, the implementation of closed innovation tends to elongate product life cycles, whereas open innovation shortens them. The implementation of open innovation harnesses both internal and external resources, necessitating an increased reliance on tacit knowledge throughout the innovation process.

Table 2.1 Differences between open and closed innovation Adapted from Dahlander and Gann, 2010

Open Innovation	Closed Innovation
Extensive product variety	Limited product variety
Low product life cycle	High product life cycle
More externalities	No externalities
Much more tacit knowledge is required	Less tacit knowledge is required

Open innovation practices are grounded in the mechanisms of knowledge transfer, which are delineated as inbound or outbound, as illustrated in Figure 2.2 Inbound open innovation refers to the incorporation of external knowledge into the firm, while outbound open innovation involves sharing the firm's internal knowledge with external entities. Firms may also engage in concurrent inbound and outbound processes by collaborating with diverse stakeholders.

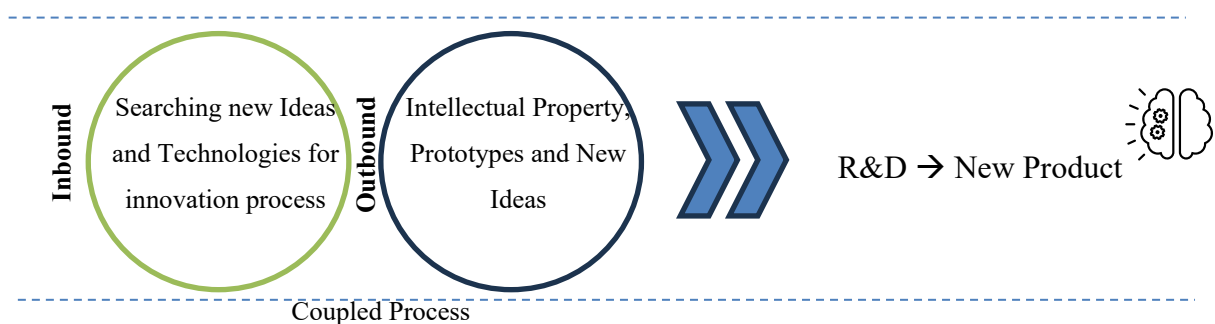


Figure 2.2 Three types of open innovation processes (inbound, outbound and coupled). Adapted from Gassmann and Enkel, 2004

Dahlander and Gann (2010) categorize inbound processes into sourcing and acquiring, and outbound processes into revealing and selling, as illustrated in Figure

2.3. Sourcing entails collaborative efforts between internal resources and external knowledge without involving monetary transactions. Conversely, the acquiring process encompasses all pecuniary activities. For instance, International Business Machines (IBM) allocates significant resources to engage with stakeholders and various external sources to gather and integrate information into internal projects and ventures. Similarly, Cisco invests in startups to boost its appeal and enhance its innovation processes (Gassmann and Enkel, 2004).

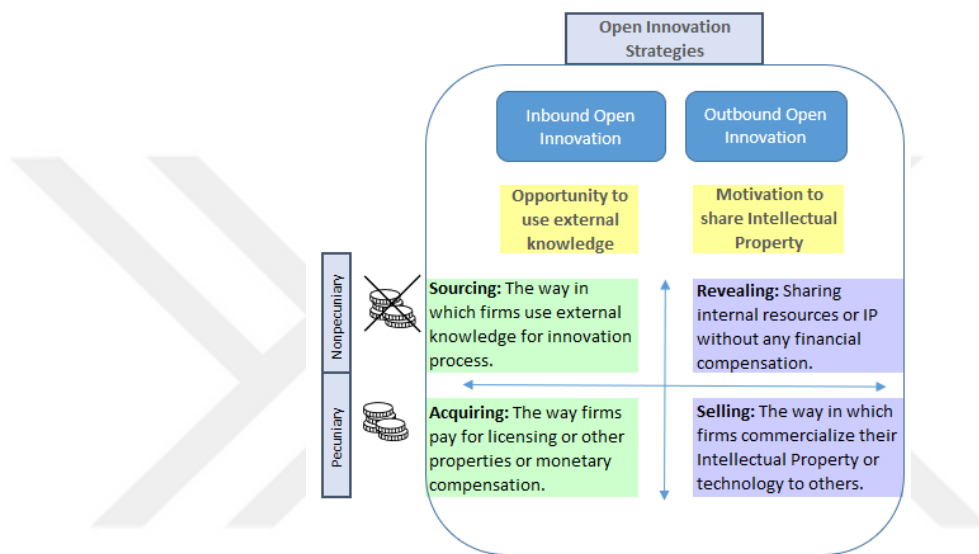


Figure 2.3 Open innovation strategies. Adapted from Leitão et al., 2020

In the outbound open innovation paradigm, internal resources are made accessible to external entities through the processes of revealing and selling. The revealing process primarily entails non-monetary exchanges and involves the dissemination of knowledge to partners, while selling entails monetary transactions. Firms that opt for outbound open innovation typically prioritize the externalization of technical expertise and intellectual property to gain a first-mover advantage in the market. This form of open innovation often involves licensing intellectual property and/or technology transfer to other firms with the aim of commercialization. For instance, Viagra, initially developed as a treatment for hypertension, evolved into a pharmaceutical product for treating erectile dysfunction through commercialization. Similarly, Botox, originally developed as a neurotoxin, found applications in reducing wrinkles in the

beauty sector. By engaging in outsourcing, firms derive various benefits such as enhanced flexibility, access to core competencies, reduced time to market, and cost savings (Haour, 1992).

Table 2.2 provides a comparison of three types of open innovation strategies. Examining the essential features of outbound innovation reveals that firms adopting this approach emphasize R&D activities and seek to optimize innovation processes to minimize costs. This is achieved through strategies such as licensing or selling intellectual property, transferring technology, or capitalizing on profitable ideas. Conversely, in the inbound type, there is a greater emphasis on accumulating know-how rather than technology. The primary focus lies in procuring intellectual property, leveraging external know-how, and fostering co-development initiatives. When firms opt for a coupled process, combining both inbound and outbound strategies, it denotes a commitment to co-innovation through collaborative alliances. The overarching objective is to expedite idea generation, jointly develop innovations, and facilitate their commercialization (Mazzola et al., 2012).

Table 2.2 Three types of open innovation strategies comparison

Characteristics	Outbound Type
More R&D focus The aim is to reduce cost	Licensing or selling IP Transferring the technology through different application areas Bring the ideas
Characteristics	Inbound Type
Low tech High Know-how accumulation	External knowhow usage Buying IP or in-licensing Focus on Co-Development
Characteristics	Coupled Type
Focus on creating alliances Creating standard settings for the products Creating complementary products	Combining the inbound & outbound processes Integrating external knowledge and technology and internal competencies and know-how

Below the unwritten implicit rules of open innovation are listed (Chesbrough and Appleyard, 2017; Dodgson et al., 2006; Witzeman et al., 2006).

- 1) Not all smart persons need to be employees of the firm but can work with them.
- 2) Significant added value can be generated through external R&D resources; however, internal R&D must also play a crucial role in contributing to the overall value created.
- 3) No need to be the creator of an idea to benefit.
- 4) Establishing an effective business model is more crucial than being the first to enter the market.
- 5) The one that creates better use with ideas created internally or externally wins.
- 6) While profiting from other firms' usage of intellectual property of yours, you should also buy others' intellectual properties that will benefit your business model.

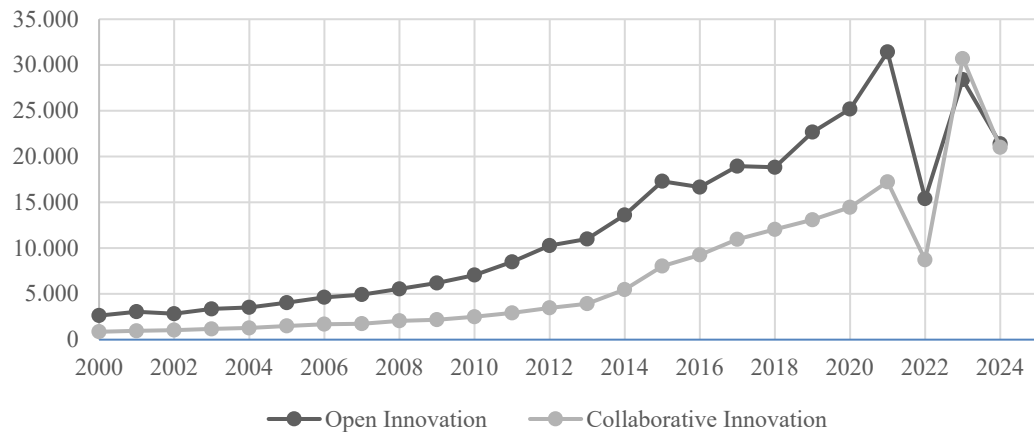
The 4 fundamental challenges posed by open innovation are discussed below.

1. Maintaining motivation for the continuity of the internal innovation process, (West and Gallagher, 2006; Sieg et. all., 2010; West and Bogers, 2004).
2. Finding the right external source for your innovation process and incorporating it into your internal processes, (Elmquist et. all., 2009)
3. To maintain the motivation of the external resources that supply intellectual property to your use (Chesbrough, 2003a; Henkel, 2006)
4. Sharing intellectual property(Chesbrough, 2003a; Henkel, 2006).

In the fifth generation of the innovation process, the significance of coordination and adaptability has been underscored (Meissner and Kotsemir, 2016). Operations that are parallel-integrated and a commitment to technological accumulation have intensified in importance. A fundamental shift has occurred in perceiving innovation as not solely sequential but inherently cross-functional and frequently involving multiple actors. Firms have begun to establish networks not only within the market but also with key suppliers, customers, competitors, and other organizations deemed talented and valuable collaborators in the innovation process. As depicted in Graph 2.1 below, collaborative innovation has started to be explored and adopted alongside open

innovation. The following section will provide a thorough analysis of collaborative innovation.

Paper quantities related to open & collaborative innovation based on years



Graph 2.1 Paper quantities related to open and collaborative innovation based on years; Source: Science Direct Website, accessed on 09.04.22

2.4 Collaborative Innovation

Before delving into collaborative innovation, it is imperative to clarify the distinctions among the terms: coordination, cooperation, and collaboration, as depicted in Figure 2.4. Coordination pertains to the organized and efficient execution of tasks or activities within a unified framework. Cooperation involves individuals or entities working together or jointly pursuing a common goal. In contrast, collaboration entails a deeper level of engagement wherein individuals or entities actively work together to create or develop something new. Collaboration necessitates dense interdependent connections, frequent communication, and the sharing of knowledge or resources among the involved parties.

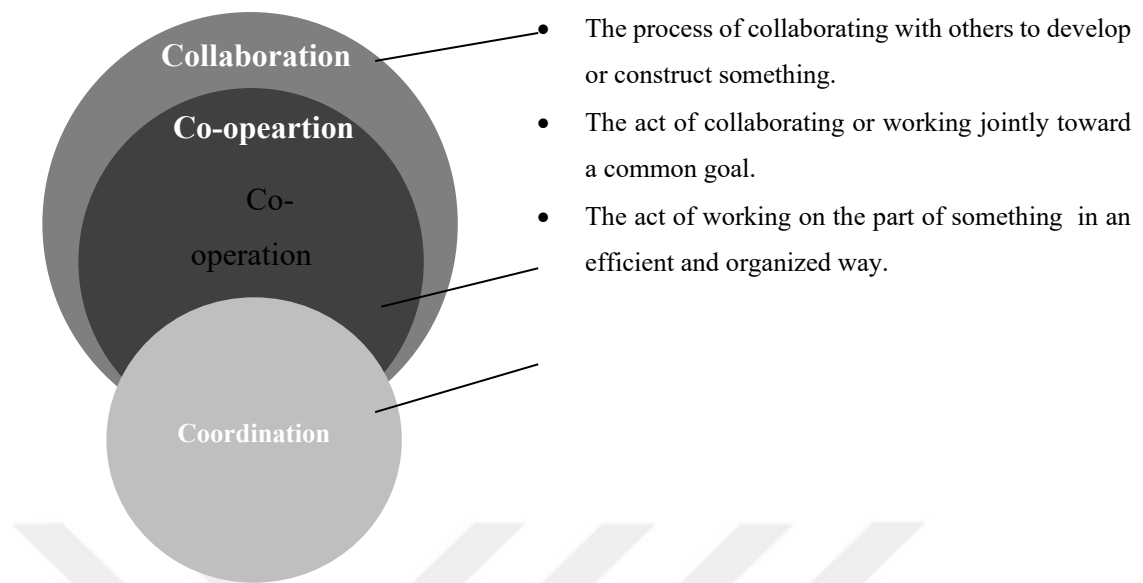


Figure 2.4 Explanations of the terms “coordination, co-operation & collaboration”. Adapted from Basco-Carrera et. al., 2017

As firms have started to gain insights from their suppliers, peers, and competitors, technological advancements have driven the development of a new innovation paradigm known as Collaborative Innovation (Greer and Lei, 2012; Prahalad and Ramaswamy, 2004). Collaborative innovation entails the participation of various contributors, such as organizations, academic institutions, and experts, in developing new products or services (Sørensen and Torfing, 2011). Unlike traditional innovation methods, collaborative innovation emphasizes collective action, information sharing, and coordinated efforts toward achieving a common goal. Within collaborative innovation, participation extends beyond the organization itself to encompass various stakeholders such as universities, governmental bodies, and suppliers, all of whom enhance the innovation process, promoting the generation and implementation of ideas.

In the collaborative innovation process, input is solicited from a diverse array of sources including suppliers, customers, end-users, markets, or sales channels. Simultaneously, areas for improvement are identified through benchmarking practices. Feedback from these channels is then evaluated by expert teams. If a problem can be

promptly resolved, the solution is implemented, thereby concluding the process. However, if a problem requires further exploration, the collaborative innovation process is initiated. During this phase, external sources and subject matter experts are engaged. If technical knowledge can be leveraged to solve the problem, the innovation process results in the development of the product or service. Conversely, if technical expertise does not contribute to the solution, the search for a solution persists within the collaborative innovation framework.

J.J. Salopek (2000) has categorized collaboration into four types based on temporal and spatial considerations. These categories provide a basis for analyzing the development of collaborative practices as they evolve from traditional methods to contemporary collaborative environments and tools.

1. Synchronously and Remote (From Different Locations): This type of collaboration involves remote interaction facilitated by technology, enabling individuals to connect with others through virtual meeting systems, videoconferencing, messaging applications, and chat programs.
2. Synchronously and Collocated (At the same Place): This form of collaboration entails traditional face-to-face communication, typically conducted in physical meeting rooms or through the use of whiteboards.
3. Asynchronously and Remote (From Different Locations): This category of collaboration involves continuous communication utilizing IT-based meeting systems and blogs, allowing individuals to engage in discussions and share information despite being geographically dispersed.
4. Asynchronously and Collocated (At the same Place): This type of collaboration involves ongoing collaboration on shared tasks within physical meeting spaces, utilizing the same tools and resources.

In the subsequent section, we will examine the primary motivations for adopting collaborative innovation as well as the associated challenges.

2.4.1 Main Drivers and Challenges of Collaborative Innovation

2.4.1.1 Main Drivers and Benefit Points

With escalating global competition, an increasing array of firms is recognizing the strategic value of collaborative innovation ecosystems for enhancing their competitiveness and business value. Within these business ecosystems, forward-thinking firms are establishing platforms that facilitate collective work, discussion, information sharing, and problem-solving among participants, thereby enabling them to achieve their individual or global objectives. These platforms are typically interconnected and autonomous, comprising self-regulating resources that empower firms to access external insights, resources, and market opportunities.

The development process of innovative products is often characterized by complexity and uncertainty (Kostis and Ritala, 2020; Banerjee and Siebert, 2017). As a result, firms are progressively adopting collaborative innovation to access new external information sources and advance innovation through joint research and development initiatives. Research has shown that collaboration, especially when it involves pooling substantial R&D resources, facilitates the creation of more innovative products and services (Heil and Bornemann, 2018).

In today's business life, firms need to look beyond their own abilities and the resources for exploring new ideas and innovation. According to BCG research on the "Most Innovative Companies, 2019", there is a big increase in the use of partnership models for innovation. Recent innovation surveys show that there is an increase in incubator use from 59% to 75%, academic partnership from 60% to 81% and company partnership from 65% to 83%. According to the literature, we can list 3 main benefit points of the collaborative innovation view.

2.4.1.1.1 Environment of Effective and Efficient Work

With the advancement of systematic innovation theory, the innovation process is no longer confined to individuals or isolated teams (Drucker, 1985). However, despite this evolution, there remains a notable lack of effective tools or environments that comprehensively cover the collaboration process. Traditional working methods,

whether face-to-face or remote, are often not cost-effective and can pose challenges for synchronized collaboration. The emergence of technology has introduced tools such as email, blogs, and wikis, which facilitate shorter communication durations and enable easier collaboration. Many collaborative innovation ecosystems have been established to harness expertise from diverse fields. Within these ecosystems, experts, firms, and organizations can readily access the value they seek, exploring numerous pathways to achieve their objectives.

According to Adner (2006), the most remarkable innovations often result from collaborative efforts among firms, organizations, universities, or entities sharing a common goal and vision. A collaborative innovation ecosystem fosters a transparent innovation process that brings together various stakeholders, enhancing efficiency and effectiveness through collective action. Illustrated in Figure 2.5, a collaborative innovation ecosystem provides a platform where all participants articulate their needs, fostering continuous improvement within a sustainable development framework. The primary objective of these ecosystems is to translate knowledge into technology. In such an environment, collaboration emerges as a crucial determinant of success, as teams are united in their pursuit of a shared goal.

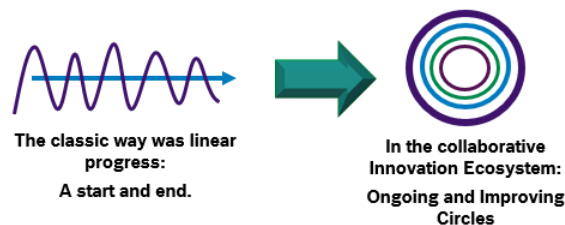


Figure 2.5 Classic innovation vs collaborative innovation-1

The ongoing and robust interaction between companies and external knowledge communities enables the development of a heightened level of innovation utilizing available knowledge and technology.

Firms drive innovation by leveraging a blend of change and professional expertise to maintain a competitive edge. This is particularly crucial in identifying innovative solutions to challenges. Startups, industry leaders, and collaborators mutually

stimulate each other to generate novel business solutions. Expert teams within firms collaborate with external experts and partners within the collaborative innovation ecosystem, enabling the swift advancement of ideas to the prototype stage and accelerating the development of innovations.

2.4.1.1.2 *The Depth of Knowledge*

Creating innovations necessitates a wealth of know-how and technology. Another hallmark of the collaborative innovation ecosystem is its ability to harness diverse skills, experiences, and future insights from various individuals. Knowledge transfer is the mechanism through which firms, organizations, departments, or units share their expertise. This transfer takes place at night both the individual and organizational levels, as illustrated in Figure 2.6.

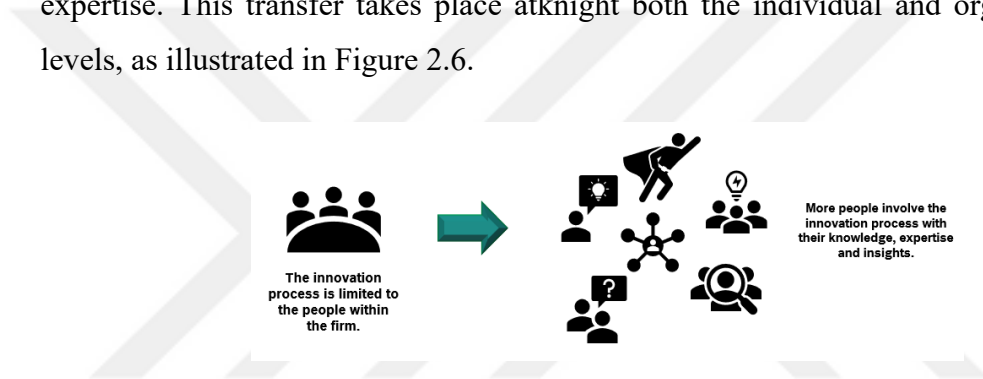


Figure 2.6 Classic innovation vs collaborative innovation-2

In some instances, crucial knowledge and expertise may reside outside of the firm, presenting challenges in terms of accessibility and feasibility from a cost perspective (Knight & Cavusgil, 2004), particularly when the underlying technology is codifiable and standardized (Narula, 2002). Externalizing such knowledge enables firms to acquire only the necessary coding without the accompanying person-embodied skills. Outsourcing allows firms to maintain minimal in-house resources and capacity. Collaborative innovation enables firms to easily access technology vendors, startups, and a wide range of partners who may offer solutions. Additionally, firms only incur costs if a solution is found, thereby reducing the cost of innovation. Moreover, in the innovation process, greater uncertainty correlates with increased risk (Banerjee and Siebert, 2017; Saghaei and Dehghanimadvar, 2020). Therefore, a collaborative innovation ecosystem that only pays for valid solution proposals becomes attractive,

especially considering that not all results achieved by companies yield successful outcomes. This fosters a risk-free working environment and reduces costs by eliminating the need to fund failed attempts. Uncertainty in the world has steadily increased over the last three centuries (World Uncertainty Index, 2024).

In some cases according to Narula(2002), firms are forced to find alliances to get access to marketing and sales channels. Even though the firms who do not need anyone for the technology, still need corporations to integrate products.

Sometimes the firm may not want to invest or spare its resources due to a very fragile and uncertain environment. In these cases, the firm may decide to share the risk with other organizations or communities. Collaborative innovation ecosystem's one of the main characteristics, knowledge share is crucial the firm who would like to decrease the costs and the risks they take.

2.4.1.1.3 Agility

As most firms grow, processes slow down. The firms lose their agility due to the large scale of systems and structures and as a result that they may lose their ability to take risks. Especially in today's markets, it is crucial to have innovation abilities for competitiveness and not to volatile market share with short product life cycles(Brandl et. all., 2018; Lill and Wald, 2021; Shuradze et. all.,2018).

Another primary concern is the need to reduce the innovation span and access supplementary knowledge and technology (Hagedoorn, 1993). In these scenarios, larger firms are often better positioned to offer significant incentives to individuals possessing the requisite knowledge and experience, enabling them to more easily engage with potential partners, as depicted in Figure 2.7.

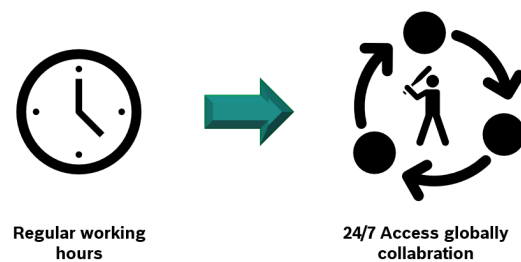


Figure 2.7 Classic innovation vs collaborative innovation – 3

Collaborative innovation ecosystems' other characteristic is to offer firms to keep their agility (Winby and Worley, 2014). When we deeply examine the collaborative innovation ecosystem, we see that ecosystem enables firms to four aspects (Nieminen, 2021).

2.4.1.1.4 Customer Oriented

While many firms primarily concentrate on monitoring their market share, observing competitors, and tracking technological advancements, their efforts often result in a misallocation of time and resources towards products or services that fail to deliver value to customers. Consequently, these offerings struggle to gain traction in the market. In contrast, within a collaborative innovation ecosystem, every participant shares a singular focus: creating value that meets customer needs and addressing or mitigating present and future challenges (McCausland, 2022; Rossman and Euchner, 2018; Tou et al., 2019). Operating within such an environment helps maintain a clear vision of what constitutes value and enables firms to stay ahead of emerging trends. Adopting this perspective not only facilitates the identification of solutions but also ensures alignment with customer-centric objectives, thereby providing firms with a competitive advantage. Furthermore, customer feedback plays a pivotal role in the innovation process, providing firms with the insights needed to improve their products and services to more effectively address customer requirements and expectations.

2.4.1.1.5 Singularly Focused Small Teams

As organizational scale increases, agility tends to diminish (Harraf et al., 2015). Consequently, to maintain agility, organizations often rely on small, focused working groups with high capabilities to overcome the challenges posed by scale. Therefore, to address this issue, organizations must cultivate teams that possess a singular focus on achieving targets, supported by appropriate environments conducive to such groups.

2.4.1.1.6 Highly Aligned and Loosely Coupled

From an agility perspective, firms should aim to minimize cross-functional meetings, foster trust between groups to facilitate swift decision-making, and reduce

ad-hoc activities. Conducting innovation activities within a focused collaborative innovation ecosystem promotes agility. Within such an environment, teams have a clear understanding of their goals, and interactions are centered around strategy and objectives rather than tactics. Notably, in a collaborative innovation environment, there are typically no cross-functional meetings or ad-hoc activities (Gilmore and Krantz, 1991; Pattinson and Chen, 2020).

2.4.1.1.7 High Expertise Density

In large-scale organizations, numerous processes are implemented to address mediocrity and mitigate issues arising from poor performance (Van de Ven, 1986; Du Plessis, 2007). Within the innovation process, firms require highly talented and expert employees who have the expertise and capabilities required to minimize non-value-added activities. In a collaborative innovation ecosystem, firms assemble teams comprised of individuals with high expertise, who then engage with numerous experts within the ecosystem.

In summary, agile teams within the collaborative innovation ecosystem innovate through five key actions:

1. Early access to solutions leveraging broad expertise and connectivity.
2. Generation of new solution ideas through interactions and collaboration.
3. Definition of problems, development of solutions, and achievement of results through collaboration within the solution development team and network.
4. Creation of early solution prototypes to establish trust and activate connections within the ecosystem.
5. Iterative refinement of early-stage solutions to continuously improve upon them.

2.4.1.1.8 Other Motivations

Participating in collaborative innovation processes offers individuals various benefits, including monetary rewards, enjoyment and satisfaction, recognition for firms or individuals, adding value to the community, and fulfilling a sense of

membership (Fernandes and Remelhe, 2016; Hansen, 2014; Lorenzo-Romero and Constantinides, 2019; Battistella and Nonino, 2012; Battistella and Nonino, 2013; Brown et al., 2019). In addition to these motivations for participation, the strengths and opportunities of the collaborative innovation ecosystem are outlined below, as depicted in Table 2.3.

Table 2.3 Strengths and opportunities

Strengths	Opportunities
Technological synergy effects	Opportunity to work with experts in the field
Brainstorming effects	Early awareness of market and customer expectation
Diversity of working environment	Reach new vertical & horizontal markets
Easy market entry	Expansion social circle of the connections
Reduced size of internal processes	Acquiring the ability to make faster decisions
Competitive spirit	Having more customer-centric teams
Vision for the future	

In addition to all the motivations and advantages for firms to use collaborative innovation, there are some barriers and weaknesses. These are discussed in the following section.

2.4.1.2 Barriers and Weaknesses of the Collaborative Innovation

2.4.1.2.1 Organizational and Hierarchical

The management's conservative stance, driven by a focus on the existing structure, may result in viewing innovation as risky and challenging (Wegrich, 2019; Lee and Shin, 2017). This kind of barrier also includes inadequate communication and inappropriate internal structures. Centralization of power in the firms may affect negatively the innovation process. The hierarchical structure also inhibits the involvement of many employees in the innovation process.

2.4.1.2.2 People Related

The nature of collaborative innovation relies not only on a firm's internal resources but also on the expertise of external experts, which can lead to resistance due to changes in the status associated with their expertise. Witte (1973) categorizes barriers

related to people into two types: i) lack of willingness and ii) lack of competence. The first category pertains to reluctance to embrace the unknown, fear of failure, and the possibility of being held accountable for it. The second category concerns insufficient knowledge about the new technology needed for the innovation (Tang and Yeo, 2003).

2.4.1.2.3 Strategy Related

This kind of barrier includes a lack of ability to network, create alliances, and readiness to develop in front of technological changes. Also include lack of resource management, difficulties to find technical equipment or a lack of R&D department existence or capability. Or the risk of destruction of the firm's capability with new technological improvements and picking the wrong technology to invest in are also defined as strategy related barriers (Sørensen and Torfing, 2011; Torfing et. all., 2019).

In addition to these barriers, some weaknesses arising from the structure of collaborative innovation are listed.

2.4.1.2.4 Weaknesses of the Collaborative Innovation

1. Loss of key know-how control
2. Loss of internal workforce motivation
3. Implementation costs

Considering all the advantages and weaknesses, according to BCG Most Innovative Companies Report (2021); to profit from the collaborative innovation ecosystem, there are 5 aspects fundamental.

1. Setting inspiring goals in line with the corporate strategy for teams to achieve goals and invent better things.
2. Awareness of the environment's dynamics which only a limited number of innovative ideas will work.
3. Defining clear Key Performance Indicators (KPI) for which steps of innovation will be rewarded.

4. Acceleration innovation by using external insights and technical know-how considering the company's strategic advantage to reach the target.

5. Welcoming innovation culture and the challenges during the innovation progress and supporting teams to tackle the problems.

Despite the challenges and barriers associated with collaborative innovation, its advantages outweigh the drawbacks. Consequently, with the advancement of technology, collaborative innovation has evolved beyond conventional methods, becoming increasingly digitized and differentiated. The next section will review the literature on the digitization of collaborative innovation.

2.5 The Evaluation of Collaboration Tools Over Time

When examining the literature, it becomes apparent that collaborative innovation has led to heightened engagement with a larger array of individuals and organizations within the business realm. This interaction progresses in tandem with technological advancements over time. Reflecting on the transition from the past to the present, relies on three main pillars concerning the management of the process. The first category involves tools that facilitate communication, the second includes essential design tools needed for developing new products or services, and the third encompasses project management tools, as detailed in Table 2.4.

Table 2.4 Review of used tool. Adapted from Marion and Fixson, 2021

	<i>2001</i>	<i>2009</i>	<i>2014</i>	<i>2015</i>
Primary communication tools during R&D	Emails	Wikis	Emails, Skype	Emails, Skype, Sharepoints
Main design tools	Paper based Sketches	Solidworks	Solidworks, Matlab, Labview	Solidworks, Matlab, Labview, Python
Project Management Tools	Excel	Project Pages	Teamwork, Google platforms, Sharepoints	Teamwork, Project Libre, Sharepoints

When examining the literature, it is commonly observed that interaction, primarily centered around communication, is predominantly facilitated through "Electronic Messaging Tools, Electronic Meeting Tools, Conference Tools, and Document Management Tools," which have the capacity to improve the sharing and collaborative work on written materials. Brief descriptions of these tools are provided below.

2.5.1 Electronic Messaging Tools

Electronic messaging tools refers to between individuals communication based on messaging infrastructure such as email or messaging applications. Emails enables to discussions between the small group. In the blog or chat services, the largest groups may communicate to each other. As of today, such messaging tools like WhatsApp, Telegram have the largest users. Still, despite the benefits, these are not fully secured. This kind of systems are

2.5.2 Electronic Meeting Tools

The electronic meeting systems are refers to computers supported cooperative work environments. In these kind of systems, users have their own computer and join the set meeting simultaneously. It allows individuals to communicate, share ideas. Most of these systems have some basic features like voting, agenda creating, discussion. The idea between the creation of the electronic meeting systems increase the efficiency of the group and overcome the disadvantages such as not being at same place. Moreover, with these tools some analysis or questionnaire may be executed easily and able to have the automatic and comprehensive documentation.

2.5.3 Conferencing Tools

This kind of communication systems does not require face to face interaction. It is mostly used between the groups who located in the different geography and need to work on the same task or problem. The main difference between the electronic meeting systems and conferencing tools is ability of asynchronously working. These systems enables its users flexibility and control over the time and access these systems from anywhere by using internet. The blogs, wiki pages, social networking sites, shared calendars and online forums may give an example of these kind of tools. The biggest

disadvantage of this kind of system is the absence of physical or social existence may cause a loss of interest.

2.5.4 Document Management Tools

This kind of tool enables its user to achieve, store and edit the documents online (e.g. Ideagen). Users easily track previous versions and reach out in case of need. Multiple reviewers can work on the same version of a document in real time and can review comments, changes and discussions from multiple reviewers. This kind of tools enables automated progress tracking and reminders. It is possible to control access and visibility of the documents and sections. For example Ideagen offers to combine the tool Q-Pulse to ensure the quality of the documentation systems. With this integration, documentation revision times reduces, automatic notifications informs the latest status. Especially during innovative product or services development phases, it is important to comply and be ready for regulatory inspections. This tools make easier to preparation.

Conversely, in terms of design tools, in the past, design engineers heavily relied on manual hand-drawing methods for product design. This often resulted in the need to restart the entire process for even minor changes. Especially In new product innovation, stakeholder involvement and evaluation were typically restricted until the production stage. Consequently, numerous iterations in the design phase led to delays in project schedules. However, with the emergence of digital design and project management tools after 2009, engineers gained the ability to iterate designs rapidly. Additionally, communication and interaction among project teams during innovation processes also witnessed significant improvements. As a result, other tools and collaborative working environments began to be integrated into professional practices as a new type of collaboration tools aimed at consolidating various needs within a common platform or approach.

In the subsequent section, the new types of collaborative working environments and tools will be examined.

2.6 Innovation Process Digitalization

Over the past years, technological advancements have transformed the way businesses operate (Marion and Fixson, 2021). Firms are keen to transform into new iterations of themselves, addressing customer preferences while also adopting new technologies to secure a competitive advantage. As a result, the innovation process has become essential for survival in a constantly evolving landscape, where outdated technologies are being replaced and business models and practices are undergoing significant changes (Agostini et al., 2020; Gobble, 2018). Unanticipated global challenges, such as the Covid-19 pandemic and abrupt geopolitical conflicts like the Russia-Ukraine war, further highlight the necessity for effective innovation in the face of uncertainty (Yoo, 2010).

These learnings highlight the importance of maintaining effective collaboration environments that provide accessibility at all times, adapting them to daily work routines for both firms and managers. For instance, partnering with customers or users to create cutting-edge products and services has become crucial for firms (Kostis and Ritala, 2020). This type of collaboration has emerged as a vital component of growth efforts for many firms, with a growing focus on direct communication and collaboration with customers to understand their needs and preferences.

As firms embark on digital transformation journeys, digitalization of innovation processes becomes imperative. Digital collaboration, facilitated by IT-based network platforms, enables external innovation, particularly through user communities or innovation communities aimed at gathering external knowledge and feedback (Van Oost et al., 2009; Hienerth et al., 2014). Digital tools and environments, including digital platforms, social media, and cloud technology, are crucial for facilitating seamless and cost-effective communication and collaboration between firms (Thomke, 2006; Chang, 2003; Bapuji and Crossan, 2004; Karakaya and Demirkan, 2015; de Reuver et al., 2018; Lee et al., 2012).

Given these developments, new collaborative working environments emerge as a solution for firms to quickly identify problems and develop solutions in sudden situations or adapt to evolving business paradigms. Consequently, the quest for new

digital environments and tools for collaborative innovation gains prominence. In the following section, I will explore the reasons why R&D is increasingly embracing new collaborative innovation tools and environments alongside digital collaboration systems.

2.6.1 New Type of Collaborative Working Environments and Tools(CWET)

Today, the use of collaborative environments and tools are increasing in parallel with technology. With the extensive proliferation of the Internet, more and more digital tools have been used instead of the old communication and collaboration environment or tools. Social media has turned into a very natural and comfortable communication and working area for people (Brisco et. all., 2016). Based on these facts, firms are trying to adapt their processes, strategies with these new kinds of collaboration environments or tools. For that purpose different kind of platforms or tools are in use that serve multiple purposes i.e. idea generation, problem-solving, co-creation, finding a marketplace, crowdsourcing, using collective intelligence, and completing microtask(Eurich et. all.,2014; Wirt and Daiser, 2018; Euchner and Ganguly, 2014). All these tools or platforms include software (SW) behind. The term social SW is used for generic products such as email or wikis etc. When these tools are utilized to facilitate various business tasks or processes, they are referred to as Collaborative Software (Dengler et al., 2011). Collaborative SW enables work on common tasks in order to achieve the common targets. By using such tools in a workplace, a collaborative working environment is constituted and people are enabled to work by providing all kinds of information and connections they may need regardless of their location. As of today, collaborative software can also enable project management and design studies. These tools actually aim to create a collaborative environment to bring together internal experts with external sources, customers, problem solvers.

Below, Table 2.5 presents the major conveniences brought by new tools and environments from three aspects:

- Early adaptation of digital tools to the innovation process
- Offering new insights and time efficiencies for individuals or teams
- Low implementation costs for new tools and environments

These advantages underscore the increasing integration of new types of tools and environments into our daily lives, facilitated by ongoing technological advancements.

Table 2.5 Tool changes and their effects. Adapted from Marion and Fixson, 2021

Changes or New Abilities in Tools and Environments	<i>Individual Based</i>	<i>Team Based</i>	<i>Organization Based</i>
Earlier Digital Tool Usage in New Product Design	Allows the design easily.	The team gets a chance to observe different iterations.	Increased knowledge-generation.
Capable New Design and Analysis Tools	A new perspective for designers and the opportunity to leverage the use of tool capabilities.	Differentiating team responsibilities	Time advantage, and increased development performance
Low Implementation Cost	Chance to try new tools for everyone for engineering activities.	Chance to try new tools for the team. Risk for knowledge management.	Allows other team members or stakeholders to join or feed design activities.
New Type of Collaboration Tools	Allows individuals to share know-how, discuss, and generate new ideas.	Allows virtual team management. Active participation is needed.	Reduction of design and project management costs. More transparent data for analysing.

These conveniences can also be expressed as motivations that drive firms to use new collaboration tools and environments while engaging in collaborative innovation as shown in Table 2.6.

Table 2.6 Summary of the main reasons why R&D use new kinds of collaborative tools and environments

Summary of the reasons why R&D use new kinds of collaborative tools and environments	Elimination of the Non Value Added Tasks
	More Easily Having Iteration of the Design
	Cost-Saving
	Synchronously and Asynchronously Communication
	Transparant Processes and Easy to Track KPIs
	Focused-Team Work
	Data Storage That is Reachable From Everywhere
	Having Insights for the Future
	Capability to integrate applications or Artificial Intelligence (AI)-driven bots

This section addresses the evolution of innovation processes, thereby highlighting the transformations that firms have undergone from the past to the present. The

following section outlines the research questions to be addressed in the thesis and the methodology that will be employed to analyze them.



CHAPTER THREE

PROBLEM DEFINITION AND DESIGN OF THE STUDY

(METHODOLOGY)

Upon reviewing the literature, it has been noted that studies have been conducted on the reasons for using tools in innovation management, their impact on communication, and their influence on the innovation process in Small and Medium-sized Enterprises (SME); however, there is a lack of detailed analysis of novel collaborative tools and environments used in collaborative innovation in R&D, and also no study has been conducted to investigate the features that might influence users while choosing which of these collaborative tools and environments to use. Therefore within this study, these two important gaps will be addressed. In the context of this study, collaborative innovation tools refer to specific applications or softwares that assist in various aspects of collaborative work and innovation processes. These tools often focus on particular tasks or functions within the broader context of collaboration and innovation. Collaborative innovation environments refer to structured spaces, often internet-based platforms, where individuals and organizations come together to crowdsource innovative solutions and address other innovation related challenges through collective effort. Throughout the thesis, “environment and platform” words and “tool and software” will be used interchangeably. This thesis have three main research questions.

Research Question 1: What are the new platforms and tools for collaborative R&D and innovation?

In the previous section the main tools used for collaborative innovation were discussed step by step, along with their evolution based on the literature; subsequently, in this thesis, the new types of collaborative innovation tools will be examined in more detail. For this purpose the following methodology is used.

A systematic review of literature and practice is performed by browsing the web using “Google Scholar”, “Google” search engines, “Web of Science” and “Scopus”. The keywords “Digital Collaboration Tools,” “Online Collaboration Tool,” “Online Innovation Management Software,” “Innovation Digitalization Tool,” “Collaborative

Innovation Platforms”, “Innovation Solution Software” and “Crowdsourcing Innovation Platforms” are used to find available relevant practices and to determine studies in which new tools and environment for collaborative R&D and/or innovation are mainly discussed. When selecting the tools and environments, application review websites such as GettApp are also utilized. Applications that received the highest ratings from the users on these sites are also considered as selection criteria. After identifying new environments and tools for collaborative R&D and innovation, these tools/environments are grouped based on at which stages of the collaborative innovation process the identified tools/environments can be effective.

Research Question 2: What are the features that might influence users while choosing collaborative tools and environments?

In delineating the features for distinguishing each tool from one another, the websites of the software are systematically reviewed. After generating a rough list of all the identified features, this list is analyzed to eliminate the recurring features. For justification, revised list of features is compared with the features provided in GettApp, Capterra which are an online platform offering reviews, comparisons, and information to help businesses evaluate and choose software solutions. Additionally, the resulting list of features is validated with an expert group managers who are directly engaged in collaborative innovation activities within the R&D department of one of combi production firm in Manisa/Turkey.

Research Question 3: Collaborative innovation software/platform selection.

With this research question, our aim is to choose the software or environment that accommodates the most beneficial features for collaborative innovation. Given that this is a multi-criteria decision-making problem, the ARAS method is chosen (Zavadskas and Turskis, 2010). The reason for choosing the ARAS method is its ease of use, simplicity, straightforward implementation, and clear interpretability. The Additive Ratio Assessment (ARAS) method is a multi-criteria decision-making (MCDM) technique employed to evaluate and rank alternatives based on various criteria. ARAS involves five key steps: formulating the decision-making matrix, normalizing data, calculating the normalized weighted matrix, determining the target

function and utility degrees, and deriving the final rankings. By using a relative indicator (utility degree), the ARAS method aims to simplify complex decision-making problems and identify the "best" alternative. This indicator reflects differences between alternatives and the ideal solution, effectively neutralizing the impact of varying measurement units. This method helps decision-makers to make informed and rational choices by considering both the relative importance of criteria and the performance of alternatives across those criteria. (Liu and Xu, 2021).

1. Define the Decision Matrix:

In this step, a matrix is created to display the basic information for each alternative across different attributes. The matrix has $m+1$ rows and n columns, where m is the number of alternatives and n is the number of attributes. Target values for attributes are determined using Equations 3.1 and 3.2 based on all other options.

$$x_{0j} = \max x_{ij} \quad (3.1)$$

$$x_{0j} = \min x_{ij} \quad (3.2)$$

x_{0j} represents the target value for the j th attribute, and x_{ij} represents the value of the i th alternative for the same attribute. Formula 3.1 is used when the j th attribute is a benefit attribute, while Formula 3.2 is used when it is a cost attribute. The decision matrix is shown below in formula 3.3:

$$\begin{bmatrix} x_{01} & \cdots & x_{0n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{bmatrix}, i=0,1,2,\dots,m; j=1,2,\dots,n. \quad (3.3)$$

2. Normalize the data

In this step, to make the criteria comparable the decision matrix is normalized. This can be done using the following formula:

$$\text{If the } j\text{th attribute is benefit attribute; } \frac{x_{ij}}{\sum_{j=1}^m x_{ij}} \quad (3.4)$$

$$\text{If the } j\text{th attribute is cost attribute; } \frac{\frac{1}{x_{ij}}}{\sum_{j=1}^m \frac{1}{x_{ij}}} \quad (3.5)$$

where is x_{ij} the performance score of alternative i for criterion j , and m is the number of alternatives.

3. Determine the normalized weighted matrix:

In this step, each attribute is assigned a weight w_{ij} , which indicates the relative importance of the different attributes. The sum of all criteria weights should equal 1. Weights can be determined using various techniques like expert judgment, Analytic Hierarchy Process (AHP), or entropy method.

$$\begin{bmatrix} \hat{x}_{01} & \cdots & \hat{x}_{0n} \\ \vdots & \ddots & \vdots \\ \hat{x}_{m1} & \cdots & \hat{x}_{mn} \end{bmatrix}, i=0,1,2,\dots,m; j=1,2,\dots,n. \quad (3.6)$$

The normalized weighted value of each alternative under each attribute is calculated by $\hat{x}_{01} = \hat{x}_{ij} \times w_j$.

4. Calculating the values of the target function and the utility degree:

After obtaining the normalized weighted decision-making matrix, the target function value for each alternative can be determined as follows:

$$S_i = \sum_{j=1}^n \hat{x}_{ij}, i = 0,1,2, \dots, m, \quad (3.7)$$

The larger the target function value, the better the alternative. The calculation shows that the target function value is directly proportional to the normalized data $\overline{x_{ij}}$ and the attribute weights w_j . In other words, these two factors influence the target function value for each alternative.

Considering that comparing the target function value of an alternative with the target value provides a clearer reflection of how target an alternative is, the degree of the alternative's utility is proposed as follows:

$$K_i = \frac{S_i}{S_0}, i=1,2,\dots,m, \quad (3.8)$$

From Equation 3.8, it is evident that the value of K_i falls within the interval $[0, 1]$. Furthermore, a higher K_i value indicates a better corresponding alternative.

5. Rank the Alternatives:

In this step, based on their utility degrees, the alternatives are ranked. The higher the utility degree, the better the alternative. These steps outline the ARAS methodology, providing a systematic approach to evaluate and rank multiple alternatives based on several criteria.

In this section, a detailed explanation of the topics to be addressed in the thesis and the methodology to be followed are explained. In the following section, the analysis performed to address the research questions and the results obtained will be explained.



CHAPTER FOUR

ANALYSIS AND RESULTS

In this section, the three research questions identified in the previous chapter will be addressed sequentially, and their solutions will be discussed.

4.1 Addressing Research Question 1

Research Question 1: What are the new platforms and tools for collaborative R&D and innovation?

To address the research question, a systematic literature review is conducted as shown in Figure 4.1. As mentioned in the section above, Google search engine, Google Scholar, Web of science and Scopus are used to identify tools and environments using the keywords "Digital Collaboration Tools," "Online Collaboration Tool," "Online Innovation Management Software," "Innovation Digitalization Tool," "Collaborative Innovation Platforms", "Innovation Solution Software" and "Crowdsourcing Innovation Platforms". The results of this study are summarized in Table 4.1 .

Table 4.1 Systematic literature review and keywords for methodology

Systematic Literature Review			
Google Search Engine	Google Scholar	Web of Science	Scopus
Keywords	Digital Collaboration Tools Online Collaboration Tool		
	Online Innovation Management Software		
	Innovation Digitalization Tool		
	Collaborative Innovation Platforms		
	Innovation solution software		
	Crowdsourcing Innovation Platforms		

Following this study, 10 collaborative environments and 65 collaborative software/tools are identified, as detailed in Table 4.1 and explained in Chapter 3, Problem Definition & Design of the Study (Methodology). The research is limited at the point where similar softwares and environments began to be obtained.

Table 4.2: Software and platforms utilized in collaborative innovation processes reached in the first stage

Collaborative Software/Tools	Collaborative Environments
Accept Mission	Crowdinnovation
Aha!	Demola
Asana	Hypios
Atlassian	Hyve
Awork	IdeaConnection
Braineet	Ideaken
Brightidea	Innoget
Canny	NineSigma
Canva	TopCoder
Chanty	Wazoku (InnoCentive)
Collaboard	
Confluence	
Craft.io	
Ezassi	
Google docs	
Google drive	
Google workspace	
Gotomeeting	
Ground Control	
HubSpot	
Hype Innovation Management	
Idea Drop	
Ideanote	
IdeaScale	
Ideawake	
Idexinnovation	
Innocentive	
Innocation	
Innolytics	
Innovation Cast	
Innovation Cloud	
Invision	
Itonics	
Jira	
Kainexus	
Keto	
Loom	
Medallia Ideas	
MeisterNote	
Microsoft teams	
MindMeister	
Miro	
Monday	
Mural	
Oracle PointPLM	
Planbox Innovate	
Planview IdeaPlace	
PPM Express	
Praxie	
Qmarkets	
SAP IM	
Skype	
Slack	
SoftExpert Suite	
Stackfield	
Trello	

Upboard	
UserVoice	
Viima	
WebEx	
Wellspring	
Yambla	
Yumana	
Zapier	
Zoom	

In the second step, the selection of software and platforms to focus on is determined based on user reviews from platforms such as GetApp and Capterra, as well as the author's subjective evaluation including feature reviews conducted on the software's own websites. Based on this, the study area is narrowed down to 3 platforms out of 10 initially considered, and reduced to 21 software applications out of the initial 65. In the subsequent section, detailed descriptions of the selected collaborative platforms and softwares are provided.

4.1.1 Collaborative Platforms / Environments

The term of crowd-sourcing refers to using harness collective knowledge from external resources (Kohler and Chesbrough, 2019; Hossain, 2012; Howe, 2006). The below mentioned platforms or environments aim to gather individuals, experts, students or organizations to create or support innovation with using crowd-sourcing phenomenon. Either it can be an organizational structure or an internet-based platform that people apply and join the community. Such structures mostly gather people in order to solve the challenges or to produce innovative solutions in predetermined project titles. Selected three platforms are explained below.

4.1.1.1 Demola

Demola, an open innovation platform established in 2008, primarily centers on a partnership model between academia and industry to develop new products and services (Demola, 2023). Students from various academic disciplines, together with their lecturers, collaborate with third-party organizations or firms to solve real-world challenges. These challenges are usually last 8 weeks and divided into 4 events to increase interaction between the students, experts and other participants including kick-off sessions and final meetings.

To support teams, specific work phases are established: the discovery phase, the ideation and prototyping phase, and the refining and packaging phase. All activities are protected by intellectual property rights. Additionally, students involved in these innovation projects receive academic credit for their contributions. The purpose of the platform is to explore even weak signals for innovation and identify change drivers. The platform seeks people who would like to stay updated, focus on possibilities and keep minds open and curious all the time. According to Demola platform, the old visions of the future are no longer enough to explore different stories and challenge narratives. Demola enables to combine firms' expertise with highly educated university students and discover what the ones wouldn't discover on their own.

4.1.1.2 Topcoder

Topcoder is a platform that connects businesses with a global community of skilled designers, developers, and data scientists. (Topcoder, 2023) It offers crowdsourced solutions for various challenges, including software development, data science, and design projects. Clients can post their projects on Topcoder, and members of the community compete to provide the best solutions. Winners are awarded prizes, and clients receive high-quality results efficiently and cost-effectively. Additionally, Topcoder provides a collaborative environment for members to learn, compete, and collaborate on projects, fostering innovation and skill development within its community.

4.1.1.3 Wazoku

Wazoku is a platform designed to facilitate innovation within organizations. (Wazoku, 2023) It offers solutions for idea management, crowdsourcing, and innovation challenges. The platform enables employees to submit ideas, collaborate on projects, and vote on the best ideas. Wazoku provides tools for managing the entire innovation process, from idea generation to implementation. It also offers features for tracking progress, measuring impact, and rewarding contributors. Wazoku aims to foster a culture of innovation within companies by providing a structured framework for capturing and developing ideas from across the organization.

4.1.2 Collaborative Software/Tools

The distinction between Collaborative Innovation tools and platforms/environments lies in their capacity to facilitate collaborative innovation by establishing a standardized interface within the organization and creating a framework to expedite collaborative innovation by eliminating non-value-added tasks in the processes. Additionally, these tools serve as access points to crowdsourcing platforms or environments, enabling access to external resources. They facilitate connections with other organizations utilizing the tool or with the organization's own customers/stakeholders. These tools encompass multiple features, ranging from project management to idea generation, supporting collaborative innovation, and problem-solving. Moreover, they can generally be integrated into artificial intelligence applications, allowing for the delegation of repetitive tasks to AI systems. These tools offer dedicated channels to support the most relevant individuals collaborating on tasks, providing synchronous or asynchronous communication. They enable voting on ideas, decision-making regarding innovative ideas, access to real-time reports, monitoring of key performance indicators (KPIs), and gaining insights into the market or future trends.

4.1.2.1 Aha!

Aha! is a comprehensive product management software solution designed to help teams develop and execute product strategies. (Aha!, 2023) It enables users to create visual roadmaps, prioritize features, and manage releases effectively. With Aha!, teams can capture ideas, define requirements, and track progress in a centralized platform. The software provides customizable templates and flexible workflows to adapt to various product development methodologies. Additionally, Aha! offers integration with popular collaboration tools and allows for real-time collaboration among team members. Overall, Aha! aims to streamline the product management process and align teams towards achieving their product goals.

4.1.2.2 Asana

Asana stands out as a versatile project management software equipped with robust features for innovation management. (Asana, 2023) Its intuitive interface and

customizable workflows ensure accessibility for users of all levels, fostering collaboration and productivity within teams. Asana facilitates efficient capture, tracking, and prioritization of innovative ideas, enabling seamless coordination and execution of innovation initiatives. With its powerful task management and communication tools, Asana empowers teams to drive innovation and achieve their goals effectively. Additionally, its integration capabilities enable seamless alignment with existing workflows, maximizing efficiency across the organization.

4.1.2.3 Atlassian

Atlassian stands out as the preferred choice for collaborative innovation due to its robust suite of collaboration tools tailored to enhance teamwork and creativity. (Atlassian, 2023) The platform offers a comprehensive set of tools, including Jira, Confluence, and Trello, which facilitate seamless communication, idea sharing, and project management includes Scrum or Agile. With Jira, teams can efficiently track tasks and progress, ensuring alignment and accountability throughout the innovation process. Confluence provides a centralized space for teams to document ideas, collaborate on documents, and share knowledge, fostering a culture of transparency and collaboration. Additionally, Trello offers an intuitive visual approach to project management, allowing teams to organize tasks and brainstorm ideas effortlessly. Together, these tools enable organizations to streamline collaboration, drive innovation, and achieve their goals effectively.

4.1.2.4 Braineet

Braineet is an innovation platform designed to accelerate projects and invest in promising ideas efficiently. (Braineet, 2023) It allows users to establish their innovation process and portfolio, consolidating all knowledge, deliverables, and data in a unified interface. The platform enables the creation of customized workflows to guide project members and facilitates performance measurement. Additionally, it offers tools and frameworks like design thinking, scrum, and agile methodologies. Integration with tools such as Microsoft Teams and Zapier allows for seamless collaboration among project members. Braineet serves as a New Product Development software, enhancing the success rates of new products by granting access to relevant

stakeholders and generating real-time development reports. It minimizes manual work and rework, ensuring optimal investment decisions and facilitating adjustments as needed throughout the development process.

4.1.2.5 Crowdworx

Crowdworx is an innovation software that facilitates idea management, innovation, and crowdsourcing within organizations. (Crowdworx, 2023) It enables collaboration among team members, streamlining the innovation process from idea generation to implementation. With customizable workflows and analytics, Crowdworx helps organizations drive innovation and increase employee engagement.

4.1.2.6 Ezassi

Ezassi is an innovation management software that centralizes idea generation, evaluation, and implementation for businesses. (Ezassi, 2023) It streamlines workflows, offers customizable templates, and integrates with other software tools to enhance collaboration and productivity. Ezassi aims to drive innovation, accelerate growth, and maintain competitiveness in the market.

4.1.2.7 HypeInnovation

HYPE Innovation offers idea management software designed to streamline innovation processes within organizations. (HypeInnovation, 2023) The platform facilitates idea generation, evaluation, and implementation, helping businesses to centralize their innovation efforts. With customizable workflows and integration capabilities, HYPE Innovation aims to drive collaboration and accelerate the development of innovative ideas.

4.1.2.8 Inolytics

Innolytics provides innovation management software to assist organizations in optimizing their innovation processes. (Inolytics, 2023) The platform supports idea generation, evaluation, and implementation, enabling businesses to centralize and streamline their innovation efforts. With customizable features and integration options,

Innolytics aims to enhance collaboration and drive successful innovation outcomes for its users.

4.1.2.9 InnovationCloud

Innovation Cloud offers a comprehensive innovation management software to help organizations streamline their innovation processes. (InnovationCloud, 2023) The platform facilitates idea generation, evaluation, and implementation, enabling businesses to centralize and manage their innovation initiatives effectively. With customizable workflows and collaboration tools, Innovation Cloud aims to drive collaboration and foster a culture of innovation within organizations.

4.1.2.10 InnovationCast

InnovationCast provides an innovation management platform designed to streamline innovation processes for organizations.(InnovationCast, 2023) The platform facilitates idea generation, evaluation, and implementation, allowing businesses to centralize and manage their innovation initiatives efficiently. With customizable features and collaboration tools, InnovationCast aims to drive collaboration and support the successful execution of innovative ideas within organizations.

4.1.2.11 InVision

InVision is a web-based visual collaboration tool specifically created for the designer to turn designs into prototypes complete with gestures and animations. (InVision,2023) All the users or stakeholders can provide feedback beginning of the design and it is possible to keep users up to date about the progress. Invision consolidates teams and tools into a cohesive, real-time collaborative environment.

Integration with the tools i.e. Teams and Zoom transforms working sessions to real-time collaboration. By using teams and Zoom app, can do calls instead of creating to-dos lists. The software enables also design tools for the teams to work collaboratively and have feedback, send reviews, and save and change easily. Thus, teams can work smarter, faster and more in sync.

4.1.2.12 Itonics

Itonics excels as an innovation management platform thanks to its robust features tailored to streamline the innovation process. (ITONICS,2023) Its strength lies in its structured approach to idea generation and evaluation, fostering transparency and collaboration. Customizable workflows ensure seamless integration with existing processes, while collaboration tools promote teamwork and knowledge sharing. Integration capabilities with other software tools further enhance its utility. Overall, ITONICS empowers organizations to efficiently manage innovation projects, driving success and growth.

4.1.2.13 Kaizenexus

Kaizenexus is pivotal in innovation management with its focus on continuous improvement methodologies, particularly Kaizen. It empowers organizations to drive incremental improvements across operations by centralizing idea capture, prioritization, and implementation. With its user-friendly interface and robust analytics, it enables real-time tracking of improvement impact. Integration with various systems ensures seamless alignment with existing workflows. Kaizenexus is essential for fostering a culture of continuous improvement and driving sustainable growth. (Kaizenexus, 2023)

4.1.2.14 Mural

The Mural is a kind of digital whiteboard that encourage collaboration with its features to encourage to create of innovation. (Mural, 2023) It is possible to collaborate with customers or stakeholders to discover new insights, visualize the ideas and possible solutions or collect design requirements for prototyping. Teams can work together in real-time or asynchronously, and can talk about new ideas, and insights. The tool aims to reveal brainstorming and ideation for innovation. The tool can be integrated with Microsoft Team, Zoom, and Webex. Mural creates collaboration spaces to empower users to innovate

4.1.2.15 Praxie

Praxie stands out as a user-friendly innovation management tool, emphasizing simplicity and accessibility. (Praxie,2023) Praxie is a cloud-based tool that provides solutions for innovation and design thinking, change management, manufacturing operations, project management, process digitization, and consulting. Tool aim is to get teams instantly focused and collaborating faster. It includes market scanning tools to collect data which becomes insights. The platform has its own library to scan data resources from internal and external databases. Also, it enables market scanning and creates your own growth platform to prioritize and discuss the trends, emerging market spaces or future disruptions. The program offers the best practice templates to create ideas and supports moving these ideas through to products or services by setting phases or gates where you can assess.

4.1.2.16 PPM Express

PPM Express is a standout innovation management tool renowned for its simplicity and effectiveness. Unlike many other solutions, PPM Express prioritizes ease of use, ensuring accessibility for users of all levels. It provides organizations with a streamlined platform to efficiently capture, evaluate, and implement innovative ideas. PPM Express facilitates informed decision-making through comprehensive analytics and reporting features, enabling organizations to assess the impact of their innovation initiatives. Its flexibility and integration capabilities ensure seamless alignment with existing workflows, maximizing utility across various industries. Overall, PPM Express is an indispensable tool for driving innovation and maintaining competitiveness in today's dynamic market landscape. (PPM Express, 2023)

4.1.2.17 Slack

Slack is a cloud-based team collaboration app designed to streamline communication and task management. (Slack, 2023) It enables real-time communication, task tracking, and updates regardless of location or time, ensuring teams stay connected and productive. The platform allows users to create channels for focused discussions, sharing, and storing data, reducing reliance on meetings and emails. Integrations with external services like Asana, GitHub, and Jira support

synchronous and asynchronous work, enhancing efficiency and collaboration. Slack's user-friendly interface fosters quick replies and informal communication, replacing traditional email exchanges and offering a more seamless team-building experience.

4.1.2.18 Stackfield

Stackfield is a web-based collaboration tool that combines all the features that teams may need to collaborate and increase productivity. (Stackfield, 2023) With team chat, you can exchange information with other users or use dedicated channels to solve the problem or create specific ideas. In these communication channels, the documents you shared are available all the time. Or to gather ideas, it is possible to create thread-based discussions and ensure important decisions remain clear, reasonable and easy to find. The tool also has features to audio, video conferencing and screen sharing to discuss design proposals or presentations or help others. Stackfield has wiki pages to share policies, templates or plans.

4.1.2.19 Qmarkets

Qmarkets is an idea and innovation management software aimed at fostering internal innovation culture and breaking down organizational silos. It enables employees to submit and collaborate on ideas, driving collective intelligence and overcoming bureaucratic structures. Additionally, Qmarkets provides an open innovation platform that involves stakeholders and clients in generating ideas for new products and services. The Q-ideate process consists of five steps: Challenge, Brainstorm, Evaluate, Implement, and Measure and Reward. The software also provides databases to discover new trends, markets, and opportunities, allowing users to assess and implement trends across their business. Scorecards and evaluation methods help determine how new trends can be incorporated into campaigns or ideas. (Qmarkets, 2023)

4.1.2.20 Viima

Viima support innovation process mainly focus via collect and manage the innovative ideas. (Viima, 2023) The platform lets the firms gather ideas from experts, customers and all the other stakeholders and help to prioritize the ideas to pick the

right ones as an open innovation platform. The ideas are automatically categorized and can be easily noticeable by users. Stakeholders can rate and criticize the ideas. It easily refines and develops ideas with your team and lets them analyze the progress of the innovation. With the pre-defined metrics, the right people rate your idea and evaluations can be used for prioritization with visualization tools. Besides these, web-based platforms such as Topcoder aim to ensure access to resources from people around the world in a short span of time. Individuals either join as solution producers or get work done on this kind of crowdsourcing platform.

4.1.2.21 Yambla

Yambla is a tool to support collaborative idea creation and innovation management for innovation. (Viima, 2023) It supports overcoming the firm's challenges by focusing on ideation. Users and stakeholders can share their promising innovative idea and solutions and they can be scored and prioritized to turn the ideas into full-fledged products or services. In the platform, you can start campaigns to collect new ideas, build dedicated teams to complete deliverables and also enables discussion with the community. In innovation management, you can set gates to decide to move forward or not and set KPIs to measure the important metrics. Yambla enables including not only R&D colleagues but also all the other stakeholders in the innovation process.

When the digital tools and platforms are examined, it is observed that they contributed in five different areas during the collaborative innovation process. Respectively those are ;

1. **Gathering and Assessing Customer Insights :** This refers to collecting the data generated from the market and decide how to shape strategy or define where to invest (Chernev, 2019). In this phase, users collaborate to gather insights from external resources and see what the latest trend is.

2. **Generating and Elaborating Ideas :** This refers to the collaborative work of the team working on the idea, producing ideas, deciding which of the ideas will be put into practice, and detailing the ideas.

3. **Task Assignment and Solution Creation:** This refers to the assignment of the tasks defined for the realization of the innovation idea studied on, or the completion of these tasks in collaboration and the creation of solution proposals.

4. **Synthetizing and Analyzing the Collected Data:** This refers to analyzing, interpreting and reporting data.

5. **Design or Development:** In the phase of design and development, users work to turn innovative ideas into a product or service. It can be considered as the prototyping stage.

The most of the digital tools and environments focuses on innovative idea generation to be more creative. They offer easy collaboration to build promising ideas for the R&D innovation. There are special tools and voting systems to decide which of these ideas to invest in. Other tools, including upBoard, Yambla, Braineet, Qmarkets, and InVision, manage the entire project lifecycle with a focus on innovation and emphasize process traceability. Therefore these tools mostly enables each step of the upper mentioned phases. On the other hand platforms like Demola aim to gather qualified experts, students or stakeholders to work togethercollaboratively to build innovative products or services. Their focus is on gathering people together, working smarter and creating together. On the other hand, Slack and Stackfield are tools that facilitate team communication in collaborative innovation processes and enable simultaneous work on documents. In this study, three platforms and 21 softwares are selected. In the Table 4.2, these platforms and softwares are categorized according to their contribution to the aforementioned five areas in the collaborative innovation proces.

Table 4.3 Platforms and softwares based on their contribution in the collaborative innovation process

Focuses on collaboration	Collaborative Platforms /Environments			Collaborative Software/Tools																				
	Demola	TopCoder	Wazoku	Aha!	Asana	Atlassian	Brainet	CrowdWorx Innovation Engine	Ezassi	HYPE Innovation	Innolytics	Innovation Cloud	InnovationCast	InVision	Ironics	KaiNexus	Mural	Praxie	PPM Express	Slack	Stackfield	Qmarkets	Viima	Yambla
Gathering and Assessing Customer Insights	X	X	X	X		X	X	X	X	X	X	X	X	X	X		X	X		X	X	X	X	X
Generating and Elaborating Ideas	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Task Assignment and Solution Creation	X	X	X	X	X	X	X	X	X	X		X	X	X			X	X			X	X		X
Synthesizing and Analyzing the Collected Data	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Design or Development	X	X	X		X	X					X			X				X						

4.2 Addressing Research Question 2:

Research Question 2: What are the features that might influence users while choosing collaborative tools and environments?

To answer the research question, the second part of this study examines 24 software programs through their respective websites, Google search engine, and GetApp to identify basic features serving as selection criteria for users. Initially, 490 distinct differentiating features are collected. These are then reduced to 129 by eliminating duplicate entries. For example, features expressed with different terms such as “Campaign Analytics,” “Campaign Management,” and “Campaign Planning” are consolidated under a single general heading, "Campaign Management," thereby removing repetitive headings.

The remaining 129 features are further grouped under general headings to consolidate similar attributes, as listed in Appendix 1. Subsequently, these 129 topics are condensed into 24 common features. In the process of reducing to 24 main features, considerations included points mentioned under "Main Drivers and Benefit Points" in Section 2, Subsection 2.4.1.1: Environment of Effective and Efficient Work, Breadth of Knowledge, Agility, Customer Orientation, Singularly Focused Small Teams, Highly Aligned and Loosely Coupled, High Expertise Density, as well as other motivations such as Technological Synergy Effects, Brainstorming Effects, Diversity of Working Environment, Easy Market Entry, Reduced Size of Internal Processes, Competitive Spirit, and Vision for the Future. These condensed 24 features align with the benefits and main motivation points provided by collaborative innovation to users.

The selected features are confirmed through interviews with six managers actively engaged in collaborative innovation activities within the R&D department of one of combi production firm in Manisa/Turkey, as shown in Figure 4.2. Descriptions of these 24 features are provided below.

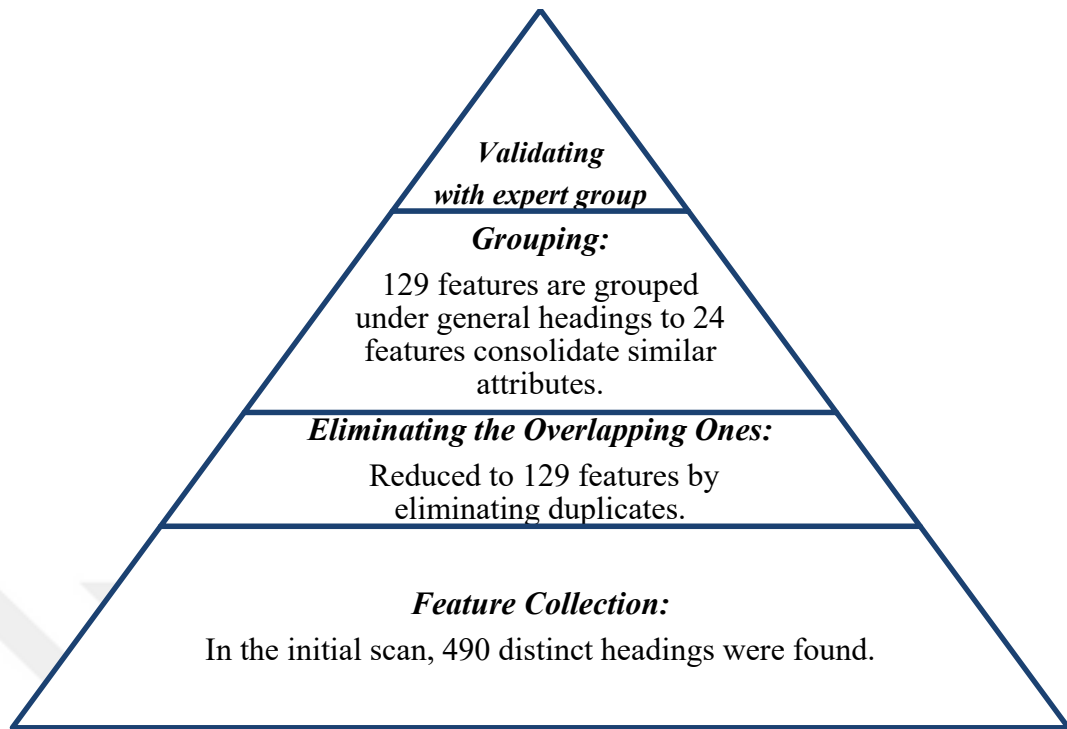


Figure 4.1 Selecting and grouping methodology of the features

These identified features are explained below:

1. **Best practice templates:** Best practice templates in collaboration software are pre-designed templates adhering to industry standards, optimizing workflows, and promoting consistency and productivity in collaborative projects.
2. **Implementation level of agile methodologies:** The "Implementation level of agile methodologies" in collaboration software involves how adeptly the software supports agile practices like Scrum, Kanban, and Waterfall project management. It ensures efficient teamwork, adaptability, and effectiveness across various project management approaches.
3. **Integrate app or bot:** It denotes the capacity for integration with other applications, such as Teams, Power BI, etc., or the capability to automate recurrent tasks.

4. **Perceived useability of user interface:** It pertains to the presence of an enhanced user interface, facilitating easier access to features and improving usability for users.
5. **Multilingualism:** The multilingualism feature enables users to operate the software in different languages, accommodating diverse language preferences for effective collaboration.
6. **Online archieving:** Ability to archieve old version of datas on cloud.
7. **Bug tracking (SW development):** Software bug tracking encompasses several processes, including prompt code reviews, assigning reviewers, and transforming any code review into a threaded discussion. It also involves commenting on specific source lines, files, or entire changesets, as well as data modeling and development.
8. **Supporting crowdsourcing:** Supporting crowdsourcing is a feature that allows a platform or system to collect ideas, solutions, or contributions from a large group of people, often through an online community. This approach leverages the collective intelligence and creativity of the crowd to address problems, generate innovative ideas, or complete tasks.
9. **Authorization:** Authorization involves granting specific groups varying levels of access rights.
10. **Customized workflow:** It pertains to the capacity to tailor the process flow to align with the firm's specific requirements.
11. **Automatic data updates:** It refers to the updates or data entries made by individuals that reach all users simultaneously.
12. **Dedicated communication channels:** It refers to customized conversation groups for teams or individuals to discuss different topics. Past conversations and shared documents can be accessed in these conversations.
13. **Desktop and mobile applications:** It refers to usage of the tool on mobile devices as well as desktop use.
14. **Launch ideation campaigns:** It refers to the idea campaigns initiated to gather ideas for a new product/service or to come up with a solution proposal for challenges.

15. **Online to-do lists / task assignments:** It refers to the ability to assign tasks related to work to be done or the availability of external resources to solve a challenge.
16. **Synchronized reporting tools:** It refers to the capability to work simultaneously on a document, code, or design with various data management features. Users can view changes in real-time, and permissions can be restricted to allow modifications to specific parts of a document or project.
17. **Synchronized/asynchronized communication:** It refers that people can access messages or entries sent while they are offline without losing data.
18. **The ability to share files:** The file-sharing feature enables users to exchange documents and data, enhancing collaboration within the platform.
19. **Track and manage team actions:** It refers to getting instant information about which tasks the team has completed, what stage the team is at, or the current status of KPIs.
20. **Video conferencing:** It enables real-time visual communication for remote meetings and discussions, enhancing collaboration.
21. **Voting and prioritizing innovation ideas:** It refers to features that allow prioritization by stakeholders, experts, or team members to decide which ideas or solution proposals should be pursued.
22. **Set gates/metrics:** It refers to establishing criteria and milestones, guiding the project with clear checkpoints, ensuring adherence to objectives.
23. **Trend monitoring:** This feature entails providing a connection or platform enabling users to monitor industry trends and follow ongoing initiatives, offering valuable insights into future developments.
24. **Audit planning:** It allows users to establish an audit questionnaire based on quality standards, such as ISO9001, ensuring compliance before progressing to the next phase.

4.3 Addressing Research Question 3:

Research Question 3: Collaborative innovation software/platform selection.

In this section, to address the third research question, the previously mentioned 24 software platforms are examined based on 24 main features. Information is gathered both from their respective websites and from applications such as GetApp. Subsequently, to verify the accuracy of the collected information, the respective authorities are contacted using the email template provided in Appendix 2, requesting confirmation of the data. Following this step, the Additive Ratio Assessment (ARAS) method, one of the multi-criteria decision-making techniques, is applied to solve the decision problem using MATrix LABoratory (MATLAB).

4.3.1 Application of the ARAS Multi-Criteria Decision-Making Method to the Problem

Below are the step-by-step instructions on how the ARAS method, whose general steps were outlined in Section 2, will be applied to solve the problem.

1. Define the Decision Matrix:

The initial step in implementing the ARAS methodology involves constructing a structured data table. This table encompasses 24 tools along with their corresponding 24 distinctive features chosen as criteria. The evaluation of the first five features is conducted linguistically using fuzzy sets that encompass 11 linguistic terms (M1 to M11), as outlined in Table 4.3. These five features are treated as fuzzy because their presence in the software can be defined within certain ranges or multiple subcategories. For instance, features like "Best Practices" or "Multilinguism" can be expressed as numerical ranges, while the feature "Implementation Level of Agile Methodologies" can be categorized based on the specific aspects it includes.

The method proposed by Chen and Hwang (1992) is applied to convert fuzzy numbers (linguistic evaluations) into crisp scores. The crisp score for a fuzzy number M can be determined as follows: Given the maximizing and minimizing sets: (Baykasoglu, 2012, pp. 579-580).

$$\begin{aligned} \mu_{max}(x) &= x \quad 0 \leq x \leq 1 & , \quad \mu_{min}(x) &= 1-x \quad 0 \leq x \leq 1 & (4.1) \\ &0 \text{ otherwise} & & 0 \text{ otherwise} \end{aligned}$$

Fuzzy max and min are defined to automatically incorporate the absolute positions of fuzzy numbers in comparison cases. The left utility score of each fuzzy number M_i is defined as $\mu_L(M_i) = \sup_x [\mu_{\min}(x) \wedge \mu_{M_i}(x)]$. The $\mu_L(M_i)$ score is a unique real number in $[0,1]$. It is the maximum membership value of intersection of M_i and fuzzy min. The correct utility score can be derived in a similar manner: $\mu_R(M_i) = \sup_x [\mu_{\max}(x) \wedge \mu_{M_i}(x)]$. $\mu_R(M_i)$ is a unique real number in $[0,1]$. Given the left and right scores, total score of M_i is defined as: $\mu_T(M_i) = [\mu_R(M_i) + 1 - \mu_L(M_i)] / 2$. Following this procedure, the crisp scores for linguistic terms (M_i) can be derived as illustrated in Fig. 4.3. These scores can also be utilized to construct Ψ and β matrices if the decision problem is modeled with fuzziness.

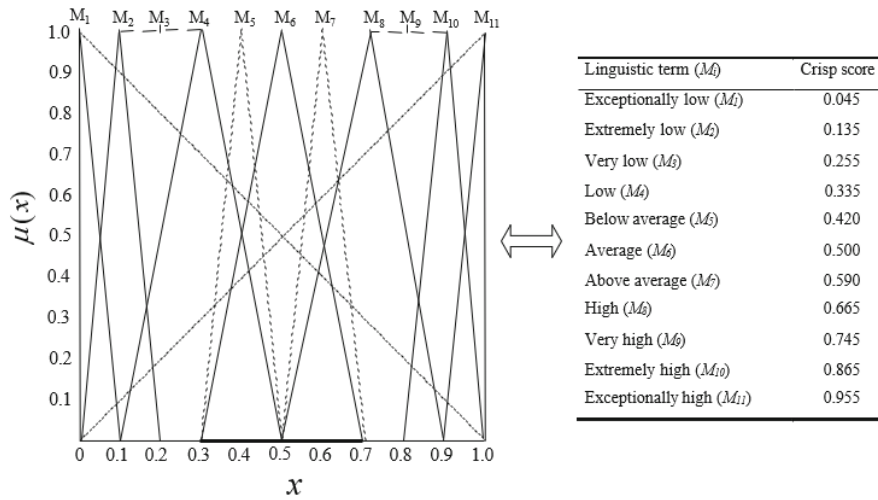


Figure 4.2 Conversion of linguistic terms to fuzzy numbers (11-point scale) for evaluating criteria scores of alternatives. Retrieved from Baykasoglu, 2012, pp. 580

Table 4.4 Qualitative scores for alternatives and linguistic terms to fuzzy number conversation (11-point scale) for evaluating criteria scores for alternatives. Adapted from Baykasoglu, 2012, pp 578-580

Qualitative Measure	Crisp Score	Linguistic Term (M_i)	Crisp Score
Exceptionally Low	0	M_1	0.045
Extremely Low	1	M_2	0.135
Very Low	2	M_3	0.255
Low	3	M_4	0.335
Below Average	4	M_5	0.420

Average	5	M_6	0.500
Above Average	6	M_7	0.590
High	7	M_8	0.665
Very High	8	M_9	0.745
Extremely High	9	M_{10}	0.865
Exceptionally High	10	M_{11}	0.955

The remaining 19 features are represented in the table as binary values (1 or 0), indicating whether the software possesses each feature as shown in Table 4.4.

The selected 24 software/platforms are evaluated to determine whether, and to what extent, they included the specified features given above. For this purpose, information provided on the official websites of the 24 identified software applications are examined and data are collected based on 24 distinct features that can be compared through tools such as Google search engine or platforms like GetApp. The collected data is verified with representatives of the software/platform companies. For this verification, the collected data are sent to the contact email addresses provided on the identified software websites, and requests for data verification are made. Reminder emails are sent to software applications from which no response is received, at intervals of one week, for a total of three times, requesting data verification. As a result of this study, data from 5 software applications (Atlassian, Yambla, Qmarkets, CrowdWorx Innovation Engine, Itonics) are confirmed.

In Table 4.4, the collected data regarding these software and their features are presented. As mentioned above, the labels "M1, M2, M3... M11" representing the first 5 features denote a Linguistic Terms ranging from exceptionally low to exceptionally high as explained above. The subsequent 1s and 0s indicate whether the mentioned software includes or does not include that particular feature. Here, 0 indicates "does not include," and 1 indicates "include".

Table 4.5 Data of features for 24 software/platforms

	Best practice templates	Integrate App or Bot	Perceived Useability of User interface	Multilingualism	Implementation level of agile methodologies	Online Archiving	Bug tracking (SW development)	Supporting Crowdsourcing	Authorization	Customized workflow	Automatic Data updates	Dedicated Communication Channels	Desktop and mobile accessibility	Launch ideation campaigns	Online To-do lists / Task assignments	Synchronized reporting tools	Synchronized/Asynchronous communication	The ability to share files	Track and manage team actions	Video Conferencing	Voting and Prioritizing Innovation Ideas	Set Gates/Metrics	Trend Monitoring	Audit Planning
Wazoku	0,045	0,335	0,500	0,665	0,255	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	0
Asana	0,335	0,865	0,745	0,665	0,865	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0	1	1	0	1
Viima	0,135	0,420	0,500	0,590	0,500	0	0	1	1	1	1	1	1	1	1	0	1	1	1	0	1	1	0	0
Slack	0,135	0,955	0,500	0,420	0,255	1	0	1	1	0	0	1	1	0	1	1	1	1	0	1	0	0	0	0
Praxie	0,665	0,665	0,745	0,045	0,865	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Atlassian	0,335	0,955	0,745	0,665	0,865	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1
Yambla	0,665	0,255	0,500	0,955	0,255	1	0	1	1	1	1	1	1	1	1	0	1	1	1	0	1	1	1	0
Braineet	0,420	0,955	0,500	0,590	0,865	1	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	0
Qmarkets	0,255	0,865	0,665	0,865	0,500	1	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1
InVision	0,665	0,665	0,665	0,045	0,500	1	0	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0	0	0
Mural	0,955	0,865	0,500	0,045	0,500	1	0	1	1	1	1	1	1	0	1	0	1	1	1	0	1	0	0	0
Stackfield	0,135	0,255	0,500	0,135	0,500	1	0	1	1	0	1	1	1	1	1	0	1	1	1	1	0	0	0	0
Aha!	0,335	0,865	0,500	0,045	0,500	0	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	0	0
InovationCloud	0,135	0,135	0,500	0,135	0,255	1	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	0
InnovationCast	0,255	0,135	0,500	0,590	0,500	1	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	0
Inolytics	0,255	0,135	0,255	0,865	0,865	0	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	0	1
HYPE Innovation	0,420	0,255	0,665	0,045	0,255	1	0	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	0
PPM Express	0,665	0,335	0,665	0,045	0,500	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0
CrowdWorx	0,420	0,590	0,665	0,745	0,255	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Itonics	0,665	0,420	0,665	0,135	0,255	1	0	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	0
Ezassi	0,255	0,420	0,500	0,045	0,255	0	0	1	0	1	1	1	1	0	1	1	1	1	1	0	1	1	1	0
KaiNexus	0,665	0,135	0,500	0,045	0,335	1	0	0	1	1	1	1	1	0	1	0	1	1	1	0	1	1	0	1
Demola	0,045	0,045	0,665	0,045	0,255	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
TopCoder	0,045	0,045	0,665	0,045	0,255	0	1	1	0	0	1	0	1	1	1	1	1	1	0	0	0	0	1	0

2. Normalize the Data:

In this step, the decision matrix is normalized to make the criteria comparable. The maximum values for each row in the table, which includes data for a total of 24 software and environment instances, are identified. Each value in a row is then divided by the maximum value of that row to normalize the data.

This is done using the following formula:

$$\text{If the } j\text{th attribute is benefit attribute; } \frac{x_{ij}}{\sum_{j=1}^m x_{ij}} \quad (3.4)$$

Table 4.6 The normalized data matrix

	Best practice templates	Integrate App or Bot	Perceived Useability of User interface	Multilingualism	Implementation level of agile methodologies	Online Archiving	Bug tracking (SW development)	Supporting Crowdsourcing	Authorization	Customized workflow	Automatic Data updates	Dedicated Communication	Desktop and mobile accessibility	Launch ideation campaigns	Online To-do lists / Task assignments	Synchronized reporting tools	Synchronized/Asynchronous communication	The ability to share files	Track and manage team actions	Video Conferencing	Voting and Prioritizing Innovation Ideas	Set Gates/Metrics	Trend Monitoring	Audit Planning
Wazoku	0,047	0,351	0,671	0,696	0,295	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	0
Asana	0,351	0,906	1,000	0,696	1,000	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0	1	1	0	1
Viima	0,141	0,440	0,671	0,618	0,578	0	0	1	1	1	1	1	1	1	1	0	1	1	1	0	1	1	0	0
Slack	0,141	1,000	0,671	0,440	0,295	1	0	1	1	0	0	1	1	0	1	1	1	1	0	1	0	0	0	0
Praxie	0,696	0,696	1,000	0,047	1,000	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Atlassian	0,351	1,000	1,000	0,696	1,000	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1
Yambla	0,696	0,267	0,671	1,000	0,295	1	0	1	1	1	1	1	1	1	1	0	1	1	1	0	1	1	1	0
Braineet	0,440	1,000	0,671	0,618	1,000	1	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	0
Qmarkets	0,267	0,906	0,893	0,906	0,578	1	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1
InVision	0,696	0,696	0,893	0,047	0,578	1	0	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0	0	0
Mural	1,000	0,906	0,671	0,047	0,578	1	0	1	1	1	1	1	1	0	1	0	1	1	1	0	1	0	0	0
Stackfield	0,141	0,267	0,671	0,141	0,578	1	0	1	1	0	1	1	1	1	1	0	1	1	1	1	0	0	0	0
Aha!	0,351	0,906	0,671	0,047	0,578	0	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	0	0
InovationCloud	0,141	0,141	0,671	0,141	0,295	1	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	0
InnovationCast	0,267	0,141	0,671	0,618	0,578	1	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	0
Inolytics	0,267	0,141	0,342	0,906	1,000	0	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	0	1
HYPE Inovation	0,440	0,267	0,893	0,047	0,295	1	0	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	0
PPM Express	0,696	0,351	0,893	0,047	0,578	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0
CrowdWorx	0,440	0,618	0,893	0,780	0,295	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Itonics	0,696	0,440	0,893	0,141	0,295	1	0	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	0
Ezassi	0,267	0,440	0,671	0,047	0,295	0	0	1	0	1	1	1	1	0	1	1	1	1	0	1	1	1	1	0
KaiNexus	0,696	0,141	0,671	0,047	0,387	1	0	0	1	1	1	1	1	0	1	0	1	1	1	0	1	1	0	1
Demola	0,047	0,047	0,893	0,047	0,295	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
TopCoder	0,047	0,047	0,893	0,047	0,295	0	1	1	0	0	1	0	1	1	1	1	1	1	0	0	0	0	1	0

3. Determine the normalized weighted matrix:

In this step, the normalized data matrix is obtained by multiplying the relevant data by the weights assigned to each feature. The first step, which involves determining these weights, is carried out as follows:

Each attribute is assigned a weight w_{ij} , reflecting the relative importance of the 24 attributes. To determine these weights, data is collected via a survey method to gather real user evaluations related to the 24 identified features. The survey targeted six managers actively involved in collaborative innovation activities within the R&D department of a composite production firm in Manisa, Turkey.

Users are directed to the following question:

Question: Evaluate the importance of the mentioned features within the context of Collaborative Innovation processes.

In this question, the user is asked to evaluate the relevant feature on a scale from 1 to 5, where 1 represents "very low" and 5 represents "very high." The collected responses are presented in Table 4.6. In this table, the abbreviation FT stands for the term "feature."

Table 4.7 Answers of R&D managers

	Features	Person #1	Person #2	Person #3	Person #4	Person #5	Person #6
FT1	Best practice templates	3	1	3	4	4	3
FT2	Integrate App or Bot	4	4	4	1	1	1
FT3	Perceived Useability of User interface	1	5	4	4	1	4
FT4	Multilingualism	3	5	5	5	1	5
FT5	Implementation level of agile methodologies	3	1	1	1	1	5
FT6	Online Archiving	1	3	5	5	5	5
FT7	Bug tracking (SW development)	4	1	1	1	1	5
FT8	Supporting Crowdsourcing	5	1	5	1	3	1
FT9	Authorization	4	5	1	4	3	5
FT10	Customized workflow	4	5	4	3	4	5
FT11	Automatic Data updates	4	4	5	2	4	5
FT12	Dedicated Communication Channels	3	2	1	1	4	5
FT13	Desktop and mobile accessibility	3	4	1	1	4	3
FT14	Launch ideation campaigns	4	1	1	1	3	1
FT15	Online To-do lists / Task assignments	4	5	3	3	4	5
FT16	Synchronized reporting tools	5	5	1	4	3	5
FT17	Synchronized/Asynchronized communication	2	5	3	1	3	5
FT18	The ability to share files	1	4	5	4	5	5

FT19	Track and manage team actions	4	3	1	5	1	3
FT20	Video Conferencing	1	1	1	1	3	5
FT21	Voting and Prioritizing Inovation Ideas	5	4	4	1	5	4
FT22	Set Gates/Metrics	4	5	5	1	4	5
FT23	Trend Monitoring	4	1	5	1	4	1
FT24	Audit Planning	4	3	5	1	4	5

The importance levels collected from target group through a survey are calculated using the geometric mean method as shown in Equation 4.2. For example, for the "best practice" feature, the importance ratings given by users are "3, 1, 3, 4, 4, 3." Using the geometric mean calculation, the importance level is computed as 2.75, as shown in Table 4.7. All calculated geometric means are normalized using the max normalization method which is given in equation 3.4 and are shown in the Table 4.7 below. In the problem we are addressing, all criteria are evaluated as maximum benefit criteria. These values are then normalized by dividing by the sum of the geometric weights which is 66.76 and presented in the third column of Table 4.7.

$$\text{Geometric Mean} = (\prod_{i=1}^n x_i)^{\frac{1}{n}} \quad (4.2)$$

Table 4.8: The geometric weights and normalized weights

	Features	Geometric Weight	Normalized Weight
FT1	Best practice templates	2,75	0,04
FT2	Implementation level of agile methodologies	2,00	0,03
FT3	Integrate App or Bot	2,62	0,04
FT4	Perceived Usebility of User interface	3,51	0,05
FT5	Multilingualism	1,57	0,02
FT6	Online Archieving	3,51	0,05
FT7	Bug tracking (SW development)	1,65	0,02
FT8	Supporting Crowdsourcing	2,05	0,03
FT9	Authorization	3,26	0,05
FT10	Customized workflow	4,11	0,06
FT11	Automatic Data updates	3,84	0,06
FT12	Dedicated Communication Channels	2,22	0,03
FT13	Desktop and mobile accessibility	2,29	0,03
FT14	Launch ideation campaigns	1,51	0,02
FT15	Online To-do lists / Task assignments	3,91	0,06
FT16	Synchronized reporting tools	3,38	0,05
FT17	Synchronized/Asynchronized communication	2,77	0,04
FT18	The ability to share files	3,55	0,05
FT19	Track and manage team actions	2,38	0,04
FT20	Video Conferencing	1,57	0,02
FT21	Voting and Prioritizing Innovation Ideas	3,42	0,05
FT22	Set Gates/Metrics	3,55	0,05
FT23	Trend Monitoring	2,08	0,03
FT24	Audit Planning	3,26	0,05

Table 4.9 Weighted normalized data matrix

	Best practice templates	Integrate App or Bot	Perceived Useability of User interface	Multilingualism	Implementation level of agile methodologies	Online Archiving	Bug tracking (SW development)	Supporting Crowdsourcing	Authorization	Customized workflow	Automatic Data updates	Dedicated Communication Channels	Desktop and mobile accessibility	Launch ideation campaigns	Online To-do lists / Task assignments	Synchronized reporting tools	Synchronized/Asynchronized communication	The ability to share files	Track & manage team actions	Video Conferencing	Voting & Prioritizing Inovation Ideas	Set Gates/Metrics	Trend Monitoring	Audit Planning
Wazoku	0.00	0.01	0.03	0.03	0.01	0.05	0.02	0.03	0.05	0.06	0.06	0.03	0.03	0.02	0.06	0.05	0.04	0.05	0.04	0.00	0.05	0.05	0.03	0.00
Asana	0.01	0.03	0.04	0.03	0.02	0.05	0.02	0.00	0.05	0.06	0.06	0.03	0.03	0.02	0.06	0.05	0.04	0.05	0.04	0.00	0.05	0.05	0.00	0.05
Viima	0.01	0.01	0.03	0.03	0.01	0.00	0.00	0.03	0.05	0.06	0.06	0.03	0.03	0.02	0.06	0.00	0.04	0.05	0.04	0.00	0.05	0.05	0.00	0.00
Slack	0.01	0.03	0.03	0.02	0.01	0.05	0.00	0.03	0.05	0.00	0.00	0.03	0.03	0.00	0.06	0.05	0.04	0.05	0.00	0.02	0.00	0.00	0.00	0.00
Praxie	0.03	0.02	0.04	0.00	0.02	0.05	0.02	0.03	0.05	0.06	0.06	0.03	0.03	0.02	0.06	0.05	0.04	0.05	0.04	0.02	0.05	0.05	0.03	0.05
Atlassian	0.01	0.03	0.04	0.03	0.02	0.05	0.02	0.03	0.05	0.06	0.06	0.03	0.03	0.02	0.06	0.05	0.04	0.05	0.04	0.00	0.05	0.05	0.03	0.05
Yambla	0.03	0.01	0.03	0.05	0.01	0.05	0.00	0.03	0.05	0.06	0.06	0.03	0.03	0.02	0.06	0.00	0.04	0.05	0.04	0.00	0.05	0.05	0.03	0.00
Braineet	0.02	0.03	0.03	0.03	0.02	0.05	0.00	0.03	0.05	0.06	0.06	0.03	0.03	0.02	0.06	0.05	0.04	0.05	0.04	0.00	0.05	0.05	0.03	0.00
Qmarkets	0.01	0.03	0.04	0.05	0.01	0.05	0.00	0.03	0.05	0.06	0.06	0.03	0.03	0.02	0.06	0.05	0.04	0.05	0.04	0.00	0.05	0.05	0.03	0.05
InVision	0.03	0.02	0.04	0.00	0.01	0.05	0.00	0.03	0.05	0.00	0.06	0.03	0.03	0.02	0.06	0.05	0.04	0.05	0.04	0.02	0.05	0.00	0.00	0.00
Mural	0.04	0.03	0.03	0.00	0.01	0.05	0.00	0.03	0.05	0.06	0.06	0.03	0.03	0.00	0.06	0.00	0.04	0.05	0.04	0.00	0.05	0.00	0.00	0.00
Stackfield	0.01	0.01	0.03	0.01	0.01	0.05	0.00	0.03	0.05	0.00	0.06	0.03	0.03	0.02	0.06	0.00	0.04	0.05	0.04	0.02	0.00	0.00	0.00	0.00
Aha!	0.01	0.03	0.03	0.00	0.01	0.00	0.00	0.03	0.05	0.06	0.06	0.03	0.03	0.02	0.06	0.05	0.04	0.05	0.04	0.00	0.05	0.00	0.00	0.00
InovationCloud	0.01	0.00	0.03	0.01	0.01	0.05	0.00	0.03	0.05	0.06	0.06	0.03	0.03	0.02	0.06	0.05	0.04	0.05	0.04	0.00	0.05	0.05	0.03	0.00
InnovationCast	0.01	0.00	0.03	0.03	0.01	0.05	0.00	0.03	0.05	0.06	0.06	0.03	0.03	0.02	0.06	0.05	0.04	0.05	0.04	0.00	0.05	0.05	0.03	0.00
Inolytics	0.01	0.00	0.01	0.05	0.02	0.00	0.02	0.03	0.05	0.06	0.06	0.03	0.03	0.02	0.06	0.00	0.04	0.05	0.04	0.02	0.05	0.05	0.00	0.05
HYPE Inovation	0.02	0.01	0.04	0.00	0.01	0.05	0.00	0.03	0.05	0.06	0.06	0.03	0.03	0.02	0.06	0.00	0.04	0.05	0.04	0.02	0.05	0.05	0.03	0.00
PPM Express	0.03	0.01	0.04	0.00	0.01	0.05	0.00	0.00	0.05	0.06	0.06	0.03	0.03	0.02	0.06	0.05	0.04	0.05	0.04	0.02	0.05	0.05	0.00	0.00
CrowdWorx	0.02	0.02	0.04	0.04	0.01	0.05	0.00	0.03	0.05	0.06	0.06	0.03	0.03	0.02	0.06	0.05	0.04	0.05	0.04	0.02	0.05	0.05	0.03	0.05
Itonics	0.03	0.01	0.04	0.01	0.01	0.05	0.00	0.03	0.05	0.06	0.06	0.03	0.03	0.02	0.06	0.00	0.04	0.05	0.04	0.02	0.05	0.05	0.03	0.00
Ezassi	0.01	0.01	0.03	0.00	0.01	0.00	0.00	0.03	0.00	0.06	0.06	0.03	0.03	0.00	0.06	0.05	0.04	0.05	0.04	0.00	0.05	0.05	0.03	0.00
KaiNexus	0.03	0.00	0.03	0.00	0.01	0.05	0.00	0.00	0.05	0.06	0.06	0.03	0.03	0.00	0.06	0.00	0.04	0.05	0.04	0.00	0.05	0.05	0.00	0.05
Demola	0.00	0.00	0.04	0.00	0.01	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	
TopCoder	0.00	0.00	0.04	0.00	0.01	0.00	0.02	0.03	0.00	0.00	0.06	0.00	0.03	0.02	0.06	0.05	0.04	0.05	0.00	0.00	0.00	0.00	0.03	0.00

4. Calculating the values of the target function and the utility degree:

The first step is to calculate the value of the target function for each alternative (S_i) by summing each row in the normalized weighted decision matrix, as illustrated in Table 4.9.

Table 4.10 S_i calculation: determining to sum of each row

$\sum Row_i$	R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8	R_9	R_{10}	R_{11}	R_{12}	R_{13}	R_{14}	R_{15}	R_{16}	R_{17}	R_{18}	R_{19}	R_{20}	R_{21}	R_{22}	R_{23}	R_{24}
Sum	0,800	0,846	0,658	0,500	0,901	0,909	0,769	0,825	0,880	0,678	0,658	0,539	0,652	0,750	0,784	0,754	0,740	0,748	0,887	0,760	0,639	0,689	0,107	0,437

The second step is to define (S_0) and calculate (K_i). To do this, first identify the maximum values of each column, as shown in Table 4.10.

Table 4.11 Defining the max values of each column

$Column_{i_{max}}$	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}	C_{18}	C_{19}	C_{20}	C_{21}	C_{22}	C_{23}	C_{24}
Max Values	0,04	0,03	0,04	0,05	0,02	0,05	0,02	0,03	0,05	0,06	0,06	0,03	0,03	0,02	0,06	0,05	0,04	0,05	0,04	0,02	0,05	0,05	0,03	0,05

After defining the maximum values of each column, it is calculated to $\sum S_0 = 0.97$. Then, K_i is determined, as shown in Table 4.11.

Table 4.12 K_i Calculation

$K_i = \frac{S_i}{\sum S_o}$	K_1	K_2	K_3	K_4	K_5	K_6	K_7	K_8	K_9	K_{10}	K_{11}	K_{12}	K_{13}	K_{14}	K_{15}	K_{16}	K_{17}	K_{18}	K_{19}	K_{20}	K_{21}	K_{22}	K_{23}	K_{24}
Value	0,825	0,872	0,678	0,516	0,929	0,937	0,792	0,851	0,908	0,699	0,678	0,556	0,672	0,773	0,808	0,777	0,762	0,771	0,914	0,783	0,659	0,710	0,111	0,451

5. Rank the Alternatives:

In this step, the ranking is based on the utility degrees of the alternatives. Alternatives with higher utility degrees are considered better. The rank of each alternative is indicated in parentheses next to it.

Alternative 1 = 0.824708 (7)

Alternative 2 = 0.872187 (5)

Alternative 3 = 0.678500 (17)

Alternative 4 = 0.515861 (22)

Alternative 5 = 0.928969 (2)

Alternative 6 = 0.936957 (1)

Alternative 7 = 0.792377 (9)

Alternative 8 = 0.850853 (6)

Alternative 9 = 0.907636 (4)

Alternative 10 = 0.699345 (16)

Alternative 11 = 0.678284 (18)

Alternative 12 = 0.555814 (21)

Alternative 13 = 0.672130 (19)

Alternative 14 = 0.772892 (12)

Alternative 15 = 0.808472 (8)

Alternative 16 = 0.777217 (11)

Alternative 17 = 0.762432 (14)

Alternative 18 = 0.771132 (13)

Alternative 19 = 0.914156 (3)

Alternative 20 = 0.783212 (10)

Alternative 21 = 0.658734 (20)

Alternative 22 = 0.710352 (15)

Alternative 23 = 0.110572 (24)

Alternative 24 = 0.450778 (23)

Based on the ranking the alternative 6 is defined as better option.

In the following chapter, the study's conclusions and discussion will be presented. It will be explained, respectively, what the output of the study is, how our findings contribute to the literature, how our findings can be used by others, the constraints we faced while conducting the study, and finally, what future research can focus on.

CHAPTER FIVE

CONCLUSION AND DISCUSSION

This section will present the findings identified throughout the thesis and the discussions related to these findings.

5.1 Summary and Main Outcomes of the Study

In the thesis research, three research questions were identified and addressed.

- 1) What are the new platforms and tools for collaborative R&D and innovation?
- 2) What are the features that might influence users while choosing collaborative tools and environments?
- 3) Collaborative innovation software/platform selection.

To answer these questions, new types of collaborative innovation softwares and environments were first examined individually, and the focus of the study was determined with certain constraints. Then, these new types of tools were analyzed, revealing that they fall into two distinct categories: Collaborative Innovation Platforms and Collaborative Innovation Softwares. Following this, the phases of collaborative innovation to which these tools contribute were identified.

For the second question, the features of all identified softwares and platforms were examined individually. These features were cross-checked with some software comparison sites mentioned in the thesis, and redundant features were eliminated, resulting in a final list of 24 features. These 24 features were then investigated to determine whether and how each software and platform contained them. The findings were sent via email to relevant parties for confirmation.

For the final question, the aim was to determine which of these tools would provide the maximum benefit to the user. To answer this, the ARAS methodology, one of the multi-criteria decision-making methods, was applied. According to the results of the research, Atlassian software was selected as the best application.

5.2 Contribution to theory

The thesis research addresses a notable gap in the literature regarding collaborative innovation tools. Prior to this study, there was no detailed research on the specific environments and softwares available for collaborative R&D and innovation. This

thesis contributes by identifying and analyzing new types of collaborative platforms and software, categorizing them into Collaborative Innovation Platforms and Collaborative Innovation Tools. It further explores the phases of collaborative innovation that these tools support.

Additionally, the study systematically examined the features of these tools, reducing them to a final list of 24 distinct attributes through cross-referencing with software comparison sites. This rigorous analysis provides valuable insights into the functional capabilities of various tools and their relevance to users. Finally, by applying the ARAS methodology to determine which tool offers the greatest benefit, the research identified Atlassian software as the optimal choice. These contributions offer a comprehensive understanding of contemporary collaborative tools and provide practical guidance for their selection, significantly advancing the field.

5.3 Implications for practice

The findings of this research offer substantial benefits for real-world applications, particularly in the realm of collaborative innovation within R&D environments. By systematically analyzing and categorizing contemporary collaborative softwares and platforms, this study equips users with valuable insights to make informed selections that align with their specific project needs. The detailed examination of tool features enhances users' ability to streamline workflows, optimize communication, and improve overall operational efficiency. For instance, platforms that facilitate real-time collaboration can significantly accelerate decision-making processes and innovation cycles, while softwares with comprehensive project tracking capabilities ensure effective management and timely completion of initiatives. In practical terms, these tools support various stages of collaborative innovation, from initial brainstorming and design to development and evaluation. As a result, the research contributes positively to the field of collaborative innovation by enhancing the effectiveness and productivity of R&D projects. The practical applications of these findings promise to improve project outcomes, maximize resource utilization, and foster more successful collaborative efforts, thereby advancing the state of collaborative innovation in research and development.

5.4 Limitations and Future Research

During this study, we analyzed the selected softwares and platforms, along with their respective features, by reviewing their official websites and directly contacting the software customer services for confirmation. Due to constraints preventing access to the full versions of these applications and the lack of response from some, future research could involve individual trials of these tools and platforms, which may enhance the study with firsthand experiences. Subsequent studies may also include a comparison of the usability of these platforms and softwares for various purposes, an exploration of their impact on individual creativity, and an investigation into the personality characteristics required for their effective utilization. In this study as well, the criterion of price, which is important for users when solving the selection problem among software, has been overlooked. In future studies, research could be conducted taking this criterion into account.

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APPENDICES

Appendix 1: 129 features

Appendix 2: Email requesting data verification

Appendix 3: Problem data set

Appendix 4: Matlab code



APPENDIX 1: 129 Features

1. Access Controls/Permissions
2. Action Management
3. Ad hoc Reporting
4. Agile Methodologies
5. Alerts/Notifications
6. Animation
7. Annotations
8. API
9. Application Management
10. Approval Process Control
11. Archiving and Retention
12. Assignment Management
13. Audio Calls
14. Audit Trail
15. Authentication
16. Backlog Management
17. Benchmarking
18. Brainstorming
19. Budget Management
20. Bug Tracking
21. Business Plan Templates
22. Business Process Automation
23. Business Process Control
24. Call Conferencing
25. Call Recording
26. Campaign Management
27. Cataloging/Categorization
28. Change Management
29. Chat/Messaging
30. Client Portal
31. Cloud Computing

- 32. Collaboration Tools
- 33. Color Codes/Icons
- 34. Commenting/Notes
- 35. Communication Management
- 36. Compatibility Testing
- 37. Compliance Management
- 38. Configurable Workflow
- 39. Content Management
- 40. Cost Tracking
- 41. Crowdsourcing
- 42. Customer Journey Mapping
- 43. Customizable
- 44. Data Management
- 45. Deadline Management
- 46. Debugging
- 47. DEI Assessment
- 48. Design Management
- 49. Desktop Interface
- 50. Digital Canvas
- 51. Discussions/Forums
- 52. Document Management
- 53. Document Storage
- 54. Drag and Drop
- 55. Editing
- 56. Email Management
- 57. Employee Management
- 58. Employee Reward Programs
- 59. Evaluation Management
- 60. File Management
- 61. Forecasting / Estimating
- 62. Forms Management
- 63. Gamification

- 
64. Gantt/Timeline View
 65. Goal Setting/Tracking
 66. Graphical User Interface
 67. Graphical Workflow Editor
 68. Group Management
 69. Guest Access
 70. Historical Reporting
 71. Idea Management
 72. Image Library
 73. Innovation Management
 74. Integrated Development Environment
 75. Interaction Tracking
 76. Interactive Elements
 77. Kanban Board
 78. KPI Monitoring
 79. Lifecycle Management
 80. Milestone Tracking
 81. Mind Maps
 82. Mobile Development
 83. Mobile Interface
 84. Modeling and Simulation
 85. Multi-Campaign
 86. Multi-Channel Communication
 87. Multi-User Collaboration
 88. Performance Metrics
 89. Planning Tools
 90. Polls/Voting
 91. Prioritization
 92. Project Management
 93. Quality Management
 94. Real Time Synchronization
 95. Remote Support

96. Reports
97. Request Management
98. Resource Management
99. Retrospectives Management
100. Risk Management
101. Roadmapping
102. Role-Based Permissions
103. Scorecards
104. Search/Filter
105. Secure Data Storage
106. Social Media Integration
107. Software Development
108. Sprint Planning
109. Supports Scrum
110. Task Management
111. Team Management
112. Template Management
113. Testing/QA Management
114. Third-Party Integrations
115. Time Tracking
116. To-Do List
117. Traceability
118. Traditional Methodologies
119. Trend Analysis
120. User Management
121. UX Prototyping
122. Video Conferencing
123. Visualization
124. Web App Development
125. Web/Mobile App Development
126. Whiteboard
127. Widgets

128. Wiki

129. Workflow Management



APPENDIX 2: Email requesting data verification

Dear [Responsible Person's Name],

I trust this email finds you well.

I am reaching out to you in connection with our academic study for a master's degree. Our primary focus is to analyze the software and platforms used in collaborative innovation within the realm of Research and Development.

Enclosed are 24 features for the classification of software abilities, along with our findings sourced from your website and internet-based searches. The first four features provide details on the inclusion of specific features, and for the "Implementation of agile methodologies" feature, we have included its respective content. Beginning with "online archiving," the subsequent features assess whether your software incorporates the specified feature or not. Given the significance of this data in the context of our master's degree study, we would greatly appreciate your collaboration in confirming our findings and updating any information if necessary.

Your support in ensuring the accuracy of the data for [Your Website or Platform] is invaluable, and we are grateful for your assistance in this matter.

Thank you for your time and consideration. We eagerly await your positive response.

Best regards,

Audit Planning	
Trend Monitoring	
Set Gates/Metrics	
Voting & Prioritizing Innovation Ideas	
Video Conferencing	
Track & manage team actions	
The ability to share files	
Synchronized/Asynchronous communication	
Online To-do lists / Task assignments	
Launch ideation campaigns	
Desktop and mobile accessibility	
Dedicated Communication Channels	
Automatic Data updates	
Customized workflow	
Authorization	
Supporting Crowdsourcing	
Bug tracking (SW development)	
Online Archiving	
Implementation level of agile methodologies	
Multilingualism	
Perceived Useability of User interface	
Integrate App or Bot	
Best practice templates	
Features	[Software Name]

APPENDIX 3: Problem data set

```
# problem data

data = np.array([

['M1','M4','M6','M8','M3',1,1,1,1,1,1,1,1,1,1,1,1,0,1,1,0],

['M4','M10','M9','M8','M10',1,1,0,1,1,1,1,1,1,1,1,1,0,1,1,0,1],

['M2','M5','M6','M7','M6',0,0,1,1,1,1,1,1,1,1,0,1,1,1,0,1,0,0],

['M2','M11','M6','M5','M3',1,0,1,1,0,0,1,1,0,1,1,1,0,1,0,0,0,0],

['M8','M8','M9','M1','M10',1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1],

['M4','M11','M9','M8','M10',1,1,1,1,1,1,1,1,1,1,1,1,1,0,1,1,1,1],

['M8','M3','M6','M11','M3',1,0,1,1,1,1,1,1,1,1,0,1,1,1,0,1,1,0],

['M5','M11','M6','M7','M10',1,0,1,1,1,1,1,1,1,1,1,1,1,0,1,1,1,0],

['M3','M10','M8','M10','M6',1,0,1,1,1,1,1,1,1,1,1,1,1,0,1,1,1,1],

['M8','M8','M8','M1','M6',1,0,1,1,0,1,1,1,1,1,1,1,1,1,1,1,0,0,0],

['M11','M10','M6','M1','M6',1,0,1,1,1,1,1,1,0,1,0,1,1,1,0,1,0,0,0],

['M2','M3','M6','M2','M6',1,0,1,1,0,1,1,1,1,1,0,1,1,1,1,0,0,0,0],

['M4','M10','M6','M1','M6',0,0,1,1,1,1,1,1,1,1,1,1,1,0,1,0,0,0],

['M2','M2','M6','M2','M3',1,0,1,1,1,1,1,1,1,1,1,1,1,0,1,1,1,0],

['M3','M2','M6','M7','M6',1,0,1,1,1,1,1,1,1,1,1,1,1,0,1,1,1,0]

['M3','M2','M3','M10','M10',0,1,1,1,1,1,1,1,1,1,0,1,1,1,1,1,0,1],

['M5','M3','M8','M1','M3',1,0,1,1,1,1,1,1,1,1,0,1,1,1,1,1,1,0],

['M8','M4','M8','M1','M6',1,0,0,1,1,1,1,1,1,1,1,1,1,1,1,1,0,0],

['M5','M7','M8','M9','M3',1,0,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1],


```

```

['M8','M5','M8','M2','M3',1,0,1,1,1,1,1,1,1,0,1,1,1,1,1,0],
['M3','M5','M6','M1','M3',0,0,1,0,1,1,1,1,0,1,1,1,1,0,1,1,0],
['M8','M2','M6','M1','M4',1,0,0,1,1,1,1,1,0,1,0,1,1,1,0,1,0,1],
['M1','M1','M8','M1','M3',0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,1,0],
['M1','M1','M8','M1','M3',0,1,1,0,0,1,0,1,1,1,1,1,1,0,0,0,1,0]])

data[data == 'M1'] = 0.045

data[data == 'M2'] = 0.135

data[data == 'M3'] = 0.255
data[data == 'M4'] = 0.335

data[data == 'M5'] = 0.420

data[data == 'M6'] = 0.500

data[data == 'M7'] = 0.590

data[data == 'M8'] = 0.665

data[data == 'M9'] = 0.745

data[data == 'M10'] = 0.865

data[data == 'M11'] = 0.955

weights = np.array([0.04, 0.03, 0.04, 0.05, 0.02, 0.05, 0.02, 0.03, 0.05, 0.06, 0.06,
                    0.03, 0.03, 0.02, 0.06, 0.05, 0.04, 0.05, 0.04, 0.02, 0.05, 0.05, 0.03, 0.05])

obj_directions=["Max","Max","Max","Max","Max","Max","Max","Max","Max",
"Max","Max","Max","Max","Max","Max","Max","Max","Max","Max","Max",
"Max","Max","Max"]

targets = np.array([np.nan, np.nan, np.nan, np.nan, np.nan, np.nan, np.nan, np.nan,
np.nan, np.nan, np.nan, np.nan, np.nan, np.nan, np.nan, np.nan, np.nan,
np.nan, np.nan, np.nan, np.nan, np.nan, np.nan])

```

```
#####  
#####end of data
```



APPENDIX 4: Matlab code

```
clear;

clc;

close all;

% Load Data

Range = 'A2:X25';

data1=xlsread('data_output.xlsx',Range);

% max normalization

dataMax = max(data1,[],1);

NormDecMat = data1 ./ dataMax;

Weight = [0.04 0.03 0.04 0.05 0.02 0.05 0.02 0.03 0.05 0.06 0.06 0.03 0.03 0.02
0.06 0.05 0.04 0.05 0.04 0.02 0.05 0.05 0.03 0.05];

[m,n]=size(NormDecMat);

%The normalized matrix is weighted by multiplying each element of the matrix
from respective coefficient of significance.

for j=1:n

    WDecMat(:,j) = NormDecMat(:,j) * Weight(j);

end

% Finding max of each column

Maks=max(WDecMat);

So=sum(Maks);

% The values of utility function are approximated for each of alternatives.

for i=1:m

    S(i)=sum(WDecMat(i,:));

end
```

```

% The values of utility degree are approximated for each of alternatives.

for i=1:m

K(i)=S(i)/So;

end

%Print results.

[SortK I]=sort(K);

fprintf('The ranking is as follows\n');

for i=1:m

    k = find(SortK==K(i),1);

    fprintf('Alternative %d = %f (%d)\n',i,K(i),m+1-k);

end

```