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Keynote paper

CROWD-BASED OPEN INNOVATION: MODELS, CHALLENGES, AND TRENDS

Abstract

This article considers concepts, models, achieved results and emerging trends of the open innovation approach to organizing and conducting research and development activities in companies. The goal is to perform a comprehensive systematic analysis of literature that considers the open innovation models that focus on the collaboration of various stakeholders, including companies, academia, government, startups, individuals, and others, in the context of design and development of innovative digital services, through integration of crowdsourcing and DevOps. As a result, we propose a new framework for organizing open innovation activities using DevOps practices for digitals service development. Finally, we present examples of implementing crowd-based open innovation models in various contexts.

Key words: *Open Innovation, Crowdsourcing, DevOps, Digital Services.*

1. Introduction

Austrian economist Joseph Schumpeter (1883-1950) in the first half of the twentieth century was the first to recognize and define the concept of innovation theory. Throughout history, innovations have had a special contribution not only through the development of new products, services, and technologies but also through the progress of the entire society as a whole. As a result of the general social digital transformation, a digital economy was created, which is precisely based on innovation processes. In the conditions of market competition and the digital economy, the continuous implementation of innovation projects is necessary for the successful operation of a company. Constant

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innovative activities are necessary for a company to be competitive in the market. The main function of innovations is to introduce changes in the company that can increase its economy, effectiveness, and profitability, thus influencing the development and growth of the company (Curley & Salmelin, 2013). Digital transformation, which is innovative by its nature, brings radical changes in the organization and operations of a company. The development of various Industry 4.0 technologies, such as Internet of Things (hereinafter: IoT), big data, virtual reality and others, enabled the wider social community to define problems and offer solutions in many areas of social action (Bogdanović, et al., 2021).

According to the chronological classification of different models of innovation management (Trott, 2017), the sixth generation is represented by the open innovation model, which appeared in 2000 and continues today. Open innovation represents a model of combining internal and external ideas, intending to improve the development of new technologies.

The purpose of this article is to analyze and present an overview of the open innovation concepts and models in the context of digital transformation, with the focus on software development aspects, and propose a research and innovation platform that leverages DevOps concepts to support open innovation. In section 2 we present the main theoretical concepts of open innovation approach. Section 3 gives an overview of crowd-based open innovation models, with the focus on hackathons, startups and the role of DevOps. In section 4 we discuss the possibilities of creating a general model of crowd-based open innovation, based on the approaches in literature. Finally, section 5 presents examples of open innovation projects, followed by concluding remarks.

2. Open innovation - term and concept

The term Open Innovation was used for the first time in 2003 by Chesbrough (Chesbrough, 2003), in the paper "Open Innovation: A New Imperative for Creating and Profiting from Technology." He defined open innovation as the use of knowledge from the company and its environment, to speed up internal innovation processes with external knowledge and thus increase the market for existing internal innovations for their external placement (Chesbrough, 2012). Until the end of the 20th century, innovative activities in companies were limited by their borders. This means that those companies implemented innovative development projects exclusively under controlled conditions, with internal knowledge and resources, without any competition (Stanisavljević et al., 2023).

The closed innovation business model, due to the rising costs of technological development and the ever-shortening lifespan of new products, has faced declining efficiency (Dodgson et al., 2008). The previously closed and traditional innovation processes no longer gave the expected results (Dhal et al., 2018). This was influenced by the increased number of experts in various fields, then opportunities for capital inflow, as well as opportunities to reach innovative and high-quality solutions outside the company (Cruz & Astudillo, 2020).

The way out of the closed circle of ever-increasing costs and decreasing revenues was provided by a model of open innovation. The development of modern technologies, especially the IoT, has enabled companies to use knowledge from the immediate and wider social environment, from other companies, research organizations, educational institutions, local governments, and even directly from the citizens themselves (Santoro et al., 2018; Wang et al., 2021). Accordingly, open innovation represents a "distributed innovation process based on the management of knowledge flows beyond the boundaries of the organization" (Chesbrough & Bogers, 2014; Bogers et al., 2018). Transparency, cooperation, clear goals, finding the right channels, commitment, and rewarding participants are key factors for the success of open innovation (Durst & Ståhle, 2013; Subtil de Oliveira et al., 2018).

In the past two decades, few studies have addressed the difficulties in implementing open innovation, intending to provide managers with guidelines for managing and managing these processes, to successfully implement open innovation. The European Commission promoted the Open Innovation 2.0 approach, which was based on innovation ecosystems, cooperation, and joint value creation, to integrate and synergize innovation processes (Curley & Salmelin, 2013; Lopes et al., 2021). The emergence of the "Industry 4.0" paradigm and the development of information technologies and IoT have created the conditions for today's innovation processes to represent the integration of knowledge from the fields of education, business, public and state administration, the civil sector, and individuals themselves. These activities aim to offer new, innovative services, as well as to open new markets (Hizam-Hanafiah & Soomro, 2021; Stojanović et al., 2021). The Industrial Technology Research Institute is just one of the international R&D organizations working on a platform-based open innovation model and its generation from idea to commercialization, to create social and economic value (Wang et al., 2021).

3. Analysis of the crowd-based business model of open innovation

Models of open innovation can be generally categorized in three groups: a) Outside-In; b) Inside-Out; c) Coupled. The Outside-in model includes the use of external knowledge and the taking over of other people's discoveries and their inclusion in internal innovation processes, while the Inside-out model is aimed at the placement of internally generated knowledge to other companies (Inauen et al., 2011). The integration of Outside-In and Inside-Out models represents the combined Coupled model (Chesbrough & Bogers, 2014; Bogers, 2012; Enkel et al., 2009; Gassmann et al., 2010), which includes two or more partners who, through joint activities, manage the development of an innovation from an idea to its commercialization outside of their organizational units (Bogers et al., 2012). The focus of further analysis is on the coupled models, which include multiple stakeholders, and span across the industry, academia, government, and society participation, through crowdsourcing.

The concept of open innovation in theory and practice is based on the crowdsourcing model, in which the source of knowledge is the "mass of individuals" (crowd), which leads to better, faster and more innovative solutions (Estellés-Arolas & González-Ladrón-de-Guevara, 2012). Crowdsourcing is most often used at the beginning of the innovation process, which is crucial for its successful implementation (Sarić et al., 2022; Stanisavljević et al., 2022). According to the definition of author Jeff Howe (Howe, 2008), crowdsourcing is a process by which a certain task in the form of an open call is transferred from specialized individuals to an undefined, large group of people outside the company. With the necessary conditions met, a community will almost always perform better than employees within a single company.

Digital transformation creates conditions for unifying the processes of creating innovations, developing and exploiting software for digital products and services, as well as processes related to market research and customer relations. In digital transformation, innovative processes are more diverse and it is not possible to realize them with a single model of innovation management. The crowdsourcing platform is just one of the digital platforms for open innovation, and includes crowdsourcing, crowdfunding, microwork, social product development and the sharing economy (Abhari et al., 2022). In theory, that model is known as the Crowd-based business model of open innovation. The application of this model of open innovation enables companies to find, in addition to resources within the company itself, sources of innovation and actors of the innovation process in the business environment, as well as among citizens. Digital platforms enable all actors in the innovation process to perform all their tasks remotely and efficiently (Aggeri & Segrestin, 2007). All citizens have the opportunity to get involved in the innovative process, whether for financial or other reasons (Saebi & Foss, 2015).

Numerous digital platforms have been developed for the crowd-based business model of open innovation. They provide digital services for the creation of innovations, most often in the form of a virtual environment. According to Hallerstede (Hallerstede, 2013), digital platforms for open innovation can be divided into:

- Innovation contests and competitions (Innovation Contest)
- Innovation Community
- Innovation Marketplaces
- Innovation Toolkits
- Technologies to support innovation (Innovation Technologies)

3. 1. Hackathons and student competitions

Student competitions and *hackathon*s represent one approach to implementing the concept of open innovation in non-formal education. They were originally organized with the aim of participants developing prototype software solutions through intensive programming in a short period, over time they developed

into different models of student competitions (Briscoe & Mulligan, 2014). Companies have already recognized the value of *hackathons* as an open model of innovation, where ideas and prototypes can be created by students and other participants. Numerous *hackathons* have recently been organized as virtual events, based on the cooperation and synergy of various international and cultural teams. The shortcoming of this model of open innovation is that the focus is only on the innovation capacities of educational institutions or technology transfer, and educational goals and learning outcomes are missing.

The improvement of engineering education can be achieved through open innovation and the implementation of project-based learning in formal education. Research conducted at the Department of e-business, Faculty of Organizational Sciences, University of Belgrade showed that both of these approaches to improving engineering education yield good results and have a positive effect on learning outcomes and students. Both approaches have been implemented for teaching and learning IT education subjects, namely Blockchain technologies and IoT (Ćirković et al., 2023).

Project-based learning is already widespread and recognized as a method for developing innovative competencies in engineers. However, the disadvantage of project-based learning for open innovation is that the results obtained from the classroom often do not reach potential investors, consumers, or the market (Awuor et al., 2022).

3. 2. Startups

Startup companies are a powerful engine of open innovation. Startup companies are essentially open organizations, necessarily involved in innovation processes (Spender et al., 2017). In stimulating the growth and success of startup companies, open innovation plays a key role, as a unique challenge and opportunity. Thanks to external knowledge, resources, and networks, startup companies can accelerate their innovation processes, reduce risks and gain a competitive advantage in dynamic markets. They can use a variety of open innovation strategies, including collaboration with industry leaders and research institutions. Startups can use open innovation to fuel their growth and achieve long-term success (Budiyono, 2023). In the literature, the application of open innovation in startup companies is a relatively unexplored field, and research dealing with collaborative innovation between startups and large companies is practically non-existent. Open innovation for startups has advantages, and startup managers with experience working in or with large companies can skillfully deal with a larger partner in the innovation network (Usman & Vanhaverbeke, 2017).

3. 3. DevOps model for development management

Open innovation platforms have emerged as software solutions to facilitate collaboration between different participants in an open innovation initiative (Cruz & Astudillo, 2020). The *DevOps* model for software development management combined with the Crowd-based open innovation management model represents an integrated model for open innovation. The crowd-based business model of open innovation includes research of potential markets, new ideas, creation of innovations, services, and implementation of prototypes. In a situation where companies are in the process of digital transformation, and their products and services are digital, the DevOps software development management model is necessary for conceptual design, testing, commercialization, and exploitation of digital products and services.

A wide set of stakeholders is involved in the functioning of open innovation platforms. Platform providers are companies that implement and maintain it, and provide technical support, innovative services, legal security, and monetary compensation for the services provided. The users of the platform, on the other hand, are other companies, entrepreneurs, freelancers, public administration, the academic community, the civil sector, and citizens (Bogdanović et al., 2023).

4. Open innovation using DevOps and Crowdsourcing

Thanks to the development of IoT and social networks, instead of traditional open innovation we increasingly have Internet-based innovation. Online environments create opportunities for different ideas, products, and services. Through public sharing, open innovation and knowledge management can be linked. In this way, companies speed up their work, reduce risk and, thanks to open innovation platforms, reach innovative resources.

For a long time, triple helix was the dominant model of innovation, as an approach that focuses on the interactions between industry, academia and government (Leydesdorff, 2000). Lately, the focus is shifting to quadruple and quintuple innovation models, which add knowledge society and natural environment (Carayannis & Campbell, 2010). An illustration of the quintuple helix model of innovation is presented in Figure 1.

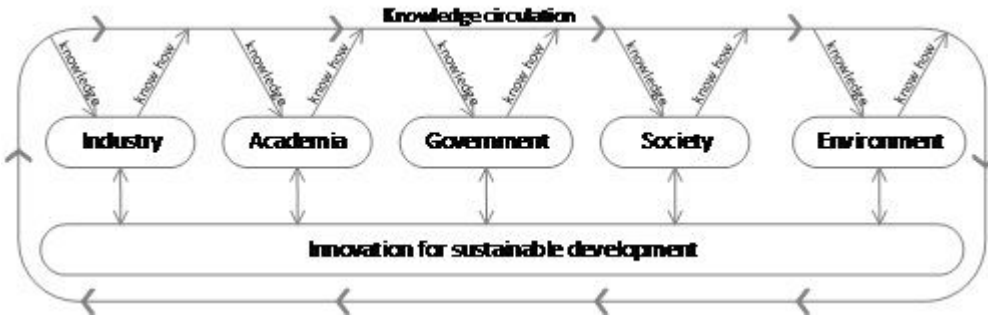

Figure 1. Quintuple helix model of innovation, based on (Carayannis et al. 2012)

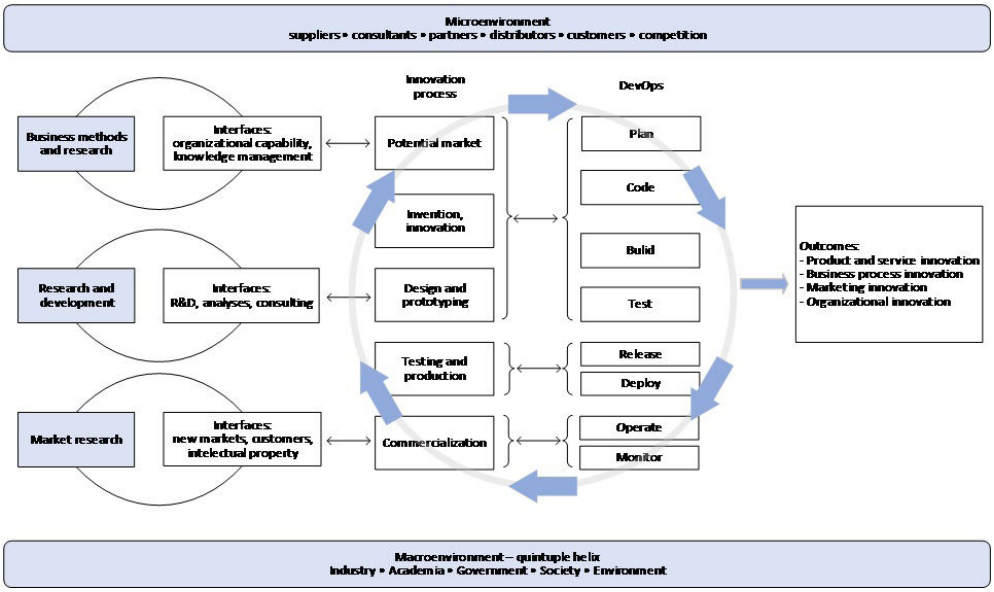

Figure 2. An integrated model for managing crowd-based open innovation with DevOps, based on (Caraça et al., 2007) (Carayannis et al. 2012) (Bogdanović et al., 2023)

However, the development of modern digital products and services is based on integration of new approaches to innovation with modern product development and software development concepts and models, such as DevOps (Bogdanović et al., 2023). Open innovation models in this context are various, and hard to be presented with one comprehensive model of innovation management. As one attempt to integrate open innovation models with modern software development approaches based on DevOps, we present an integrated model that includes a crowd-based model of open innovation management based on the chain-interactive model from the literature, DevOps approach to software development, and quintuple helix elements (Figure 2). The proposed approach is founded on crowd-based models, which rely on the participation of a large number of stakeholders, including stakeholders from macroenvironment, such as industry, academia, government, citizens and environment, as well as stakeholders from microenvironment, such as suppliers, consultants, consumers, distributors, competitors, to jointly develop sustainable solutions. In all phases, the company relies not only on internal resources and knowledge, but communications with the relevant stakeholders through a set of interfaces and communication shannels. The DevOps phases of software development correspond to phases of innovation process, as shown in the figure. Many of the innovations require some kind of software development, and thus the lifecycle of the innovative product or service has to be in line with the lifecycle of the software that serves it. Innovation outcomes may come in various areas or forms, including new products or services, new business models, new marketing strategies or techniques, or any kind of organizational innovation.

5. Examples of crowd-based open innovations

Open innovations are applied in a wide variety of fields, and the best results are achieved precisely in cases of intersectoral cooperation. Thus, for example, railways and the railway industry, as complex and multidisciplinary systems, are particularly suitable for the application of the open innovation model. In European and global railway companies, the application of the open innovation model was "an original, efficient, and high-quality response to existing problems" (Dodgson et al., 2015; Thurner & Gershman, 2014; Hanley et al., 2022).

Only in the past few years have there been numerous examples of this. "Alstom", an international company for the production of high-speed trains, has solved the problem of fallen and withered leaves, which caused adhesion between the rails and the wheels of the train, by applying open innovation ("Open Innovation in Railway: Example of AlstomTM | ideXlab"). As many as 38 companies from Great Britain and France applied to the open call of the Eurotunnel, which connects these two countries under the English Channel, with innovative proposals for improving the maintenance of railway rolling stock ("CPC and Eurotunnel Invite SMEs to Provide Railway Innovation Solutions"). Indian Railways received online over 100 thousand innovative proposals on the topic of future innovations in business ("Improving Indian Railways with Open Innovation"). The Rail Activation project, which was funded by the European Union's Horizon 2020 research and innovation program, was implemented by the Spanish railway industry association Mafex, which brings together 90 companies. The main goal of this project was to motivate and direct small and medium-sized enterprises from the railway industry to undertake workplace innovations, as part of the open innovation ecosystem. It is the first project of its kind in the railway sector (RailActivation project website http://railactivation.eu/).

When it comes to Serbian railways, an open innovation project was organized with students of the Faculty of Organizational Sciences of the University of Belgrade, to propose solutions for increasing the safety of railway traffic, based on IoT, through DevOps and crowdsourcing (Stanisavljević et al., 2023). The project included around 50 students working on solving real problems identified within the Serbian railways, both by developing new digital products and software.

Open innovation models are also increasingly present in the field of telecommunications, as telecommunications companies face market demands and find new opportunities to attract new subscribers with innovative products and services. In the period from 1985 to 2002, the mobile phone manufacturer Nokia combined various concepts related to cooperation strategies in research and development, applying the concept of open innovation in mobile telephony (Dittrich & Duysters, 2007). Such is the situation with telecom operators in Serbia, who have recognized the need to move from traditional to the concept of open innovation. These innovations are usually oriented towards smart city services based on the development of IoT technologies, cloud computing, software-defined networks, and blockchain. The development of the

crowdsourcing model enabled telco companies in Serbia to include customers in the open innovation system, to better design and develop services adapted to their needs (Sarić et al., 2022).

Governments are increasingly focusing their efforts on encouraging innovation within small and medium-sized enterprises. Thanks to this, cooperation between the Government, industry, and universities is gaining importance in the agenda of policy makers, to enable open innovation in small and medium-sized enterprises (Bertello et al., 2022). Open innovation had a particularly significant role in fostering the business model of small and medium-sized enterprises during the Covid-19 pandemic (Jabeen et al., 2023). The implementation of a digital *hackathon* in Sweden, in response to the Covid-19 pandemic by applying the model of open innovation through crowdsourcing, has led to a significant growth of the digital health community in this country (Temiz, 2021).

And while many studies dealt with open innovation in large organizations, some authors analyzed eleven open innovation projects in SMEs in four European regions and found a wide range of primary and secondary stakeholders, with different levels of power and dependence, used in these projects (Albats et al., 2020). A typical example is IBM, which, despite promising assumptions, failed to make a significant profit from Watson Health, as a general-purpose technology, because, given its characteristics, the approach to its market entry was too closed. The authors of the study that analyzed this example suggest that the very concept of open innovation would improve the appropriation of value from general-purpose technology (Yang et al., 2022).

The authors also studied open innovation at Sri Lankan universities and their cooperation with industry, to improve innovation through knowledge and technology transfer (Weerasinghe & Dedunu, 2021). Open innovation platforms are applied in tourism, where stakeholders communicate with each other, reach agreements and jointly solve problems through the platform, using predominantly constructive styles of interaction (Lalicic, 2018). Open innovations also play a significant role in social enterprises, bearing in mind that they simultaneously realize their planned social mission, but also profit, which is proven by the example of four leading social enterprises in the field of education in Indonesia (Harsanto et al., 2022). Also, open innovation contributes to a sustainable, circular economy (Jesus & Jugend, 2023), and Procter & Gamble, with its "Connect and Grow" strategy, implemented organizational and technological changes based on the model of open innovation (Dodgson et al., 2006). and open innovation is also applied in the pharmaceutical industry (Schuhmacher et al., 2013). The authors also deal with the risks that open innovation within companies entails, primarily due to aligned managerial motives and asymmetry among different stakeholders (Shaikh & Randhawa, 2022).

Innovations are crucial for the growth and development of a company's business and its competitiveness in the market. Open innovation is expressed through three different processes: acquisition of external technology; external exploitation of technology (outbound innovation); and merged innovation (Bigliardi et al., 2020). Acceptance and implementation of the open innova-

tion model depend to a large extent on the organizational culture, knowledge, attitudes, and rewards of employees, which was confirmed by research that included 528 employees from 28 different industries in 37, mostly European countries (Alassaf et al., 2020).

6. Conclusion

The increasing adoption of the open innovation model has brought with it the need to adapt the business strategies of companies to new business conditions. To make strategic sense of innovation communities, ecosystems, networks, and their implications for competitive advantage, a new approach to strategy is needed - open strategy (Chesbrough & Appleyard, 2007). An increasing number of European companies are adopting the open innovation model as a way to innovate and make better use of their business environment. Based on the experiences of 31 large European companies that are considered innovation leaders according to the annual "SEP Europes Corporate Startup Stars" ranking, corporate cooperation models and approaches are continuously developing, and companies and innovation drivers jointly open and develop their innovation projects for mutual benefit (Onetti, 2021).

From the experiences in practice, it is clear that companies that wish to ensure sustainable development need to expand their innovation capabilities in line with the quintuple helix model, include a large number of internal and external stakeholders, and create an environment for continuous improvement and innovation. When the innovation is based on IT services or includes digital transformation, DevOps principles can be of use, and support continuous innovation with continuous software development.

Future research will be organized in several directions: 1) more details about the readiness of software companies to embrace open innovation concepts beyond open source software need to be obtained; in this context, they can take the role of organizers of open innovation projects, but can also take a more proactive role in participating in crowd-based open innovation projects organized by other companies; 2) further analyses of alignment of open innovation models with DevOps is needed; although their lifecycles are compatible, more experiences from practice are needed, especially when coordination between a large number of participants is required; 3) empowering companies to embrace open innovation model is needed; although internal stakeholders frequently recognize the potential, top-management support is not always present, nor is this innovation model recognized as a strategic priority; 4) finally, is in needed to study in more details the relationships and models to integrate all the identified components of quintuple helix in an effective and productive way, and support crowd-based innovations for sustainable development through organizational models and technological infrastructures.

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