EAMR

EUROPEAN ACCOUNTING AND MANAGEMENT REVIEW

VOLUME 7, ISSUE 1, ARTICLE 3, 47-65, NOVEMBER 2020

# Open Innovation in Times of Covid-19: The case of Project OxyGEN

**Giovanna Lara Burbano**
*University of Girona*

Received October 8, 2020; accepted December 9, 2020.

## ABSTRACT

In the face of the health crisis unleashed by Covid-19, experts worldwide took on the challenge of designing a low-cost emergency ventilator that could be assembled quickly. This study analizes the successful case of the Project OxyGEN, led by the Barcelona-based design firm Protofy, which created an industrial-class emergency ventilator and obtained approval from the Spanish Ministry of Health (AEMPS) for use on patients. The project received scientific support from a local Research Hospital, and SEAT, a Volkswagen subsidiary, collaborated in the OxyGEN ventilators' mass-production. This open-hardware project sprung into action teams in more than 32 countries involved in the collaborative design process, adopted or made an iteration of the technology. These teams collaborated with suppliers, consultants, universities, and research institutes to drive this innovation forward. The case highlights the Open Innovation approach, inter-organisational relationships between firms of different sectors with research institutions, and innovation communities.

## KEYWORDS

Case study, Cooperation, Covid-19, Innovation communities, Inter-organisational relationships, Open Innovation, Open Hardware.

## ACKNOWLEDGMENT

A special thanks to Protofy and all the companies that participated in the OxyGEN project. To Kairos Cano for his valuable contribution to this study's improvement and the University of the Armed Forces ESPE for the financial support through grant No. 019-2017-CCB.

# 1. Introduction

In response to the Covid-19 pandemic, teams of experts worldwide took on the challenge of designing a low-cost emergency ventilator that could be assembled quickly. A particularly successful case is the OxyGEN Project, led by the Barcelona-based design firm Protofy. Building on MIT's production guidelines and scientific support from a local Research Hospital, Protofy created an industrial-grade emergency ventilator, which obtained approval from the Spanish Ministry of Health (AEMPS) for patients. SEAT, a Volkswagen subsidiary, collaborated with Protofy in the mass-production of OxyGEN ventilators.

The OxyGEN ventilator is an open hardware project which sprung into action teams in 32 countries. This community contributed to the design process, adopted, or made an iteration of the technology. These teams are also collaborating with suppliers, consultants, clients, universities, and research centers in their countries to drive this innovation forward.

This case study aims to describe and analyse the Project OxyGEN from the perspective of open innovation. We asked ourselves what characteristics and internal organisational practices of Protofy were remarkable to carry out this innovation during the Covid-19 pandemic and interact with the innovation community built around this open hardware project.

The paper is organized as follows: Section 2 addresses the literature review, section 3 briefly describes the methodology and data collection, section 4 presents the case, section 5 discusses the findings, and finally, section 6 draws conclusions, limitations, and future research.

# 2. Literature Review

## 2.1. Open Innovation

Open innovation holds that firms can and should use external and internal ideas and paths to market as they look to advance their technology (Chesbrough et al., 2006). As a result of firms adopting an Open innovation approach, Gassman and Enkel (2007) identify three processes: a) The outside-in process (inbound), where the integration of suppliers, customers, and external knowledge sourcing increase a company's innovativeness, b) The inside-out process (outbound), occurs through external exploitation of internal ideas in different markets, selling IP and multiplying technology, and c) The linking outside-in and inside-out processes by working in alliances with complementary companies.

Although there are more studies focused on the inbound process (e.g., Bianchi et al., 2010; Chesbrough and Crowther 2006; van de Vrande et al., 2009, Parida et al., 2012) than those on the outbound process (e.g., Lichtentaler, 2009) both show positive effects on the performance of the firm. However, there is consensus that to benefit from open innovation successfully, a firm requires absorptive capacity and some higher-order management capabilities to align inbound knowledge flows with the firm's in-house innovation activities.

Besides, Brunswicker and Vanhaverbeke (2015a) argue that the nature of the external source of knowledge (e.g., customers, suppliers, universities, research institutions, competitors, consultants) for inbound processes are different, thus the organizations, according to their internal organizational practices, adopt different strategies to take advantages of each source purposely. These strategies are (1) minimal searcher, (2) supply-chain, (3) technology-oriented, (4) application-oriented, and (5) full scope sourcing.

The minimal searcher (Type 1) does not actively interact with external sources to combine internal and external potentials. Supply-chain (Type 2) has relatively intense interactions with direct customers and suppliers compared to other external sources. Technology-oriented firms (Type 3) have a relatively high degree of cooperation with universities, research organisations, and IPR experts. The application-oriented and demand-driven innovation are characteristic of the application-oriented Searcher (Type 4). Finally, the full scope-searcher (Type 5) is heavily involved in knowledge sourcing, shows a strong interest in external ideas from various innovation sources, and built an innovation ecosystem for new ideas.

It is worth noting that the authors also suggest that these strategy types map onto four internal organizational practices for innovation that help support and enable external knowledge sourcing and alignment at strategic and operational levels: They are (1) long-term investment activities, (2) innovation strategy processes, (3) innovation development processes, and (4) innovation project control.

The first practice involves innovation management directing a company's innovation efforts toward project-focused activities whose purpose is to build long-term knowledge rather than produce short-term results (Brunswicker and Vanhaverbeke, 2015b). The implementation of innovation strategy processes helps to identify and recognise the value of new external information and knowledge and direct internal innovation activities (Nelson and Winter, 1982). The third organisational practice: innovation development, which helps to assimilate and transform new knowledge (Tidd, 2001). Finally, innovation project control is related to the firm's actions to reconfigure activities (Benner, 2009; Goffin and Mitchell, 2005) and ensure that innovation measures are carried out within budget, schedule, and satisfactory level performance (Robertson et al., 2012).

Based on the typology mentioned above, this case study examines the firm Protofy to determine its external knowledge sourcing strategy and internal organisational practices to leverage inbound knowledge flows for the OxyGEN project.

## 2.2. Innovation Communities

The first studies on innovation communities were carried out in the context of open-source software projects, typically initiated by individuals or small groups, where they are more observable the interactions between users and the role of communities. However, innovation communities have also been part of the development of physical products in a very similar way (von Hippel, 2005). In 2011, inspired by the free software movement, open-source hardware appeared. Both share similar characteristics and benefits, such as a high level of transparency in the development process, a high level of continuous improvement, and, again, high community participation (Merkel et al., 2012a).

West and Lakhani (2008) point out that communities and their role in the innovation process fit within and offer an opportunity to extend the firm-centric concept of open innovation. Considering them to be a "voluntary association of actors, typically lacking in a priori common organisational affiliation (i.e., not working for the same firm) but united by a shared instrumental goal, creating, adapting, adopting, or disseminating innovations."

Regarding intra-community interactions, the peer-to-peer community support facilitates the adoption and use of innovation (Lakhani and von Hippel, 2003). Meanwhile, identification and interaction within a community mean that innovations fuel imitation and extension by other user innovators (von Hippel, 2001).

Fitcher K. (2009) highlights the role of innovation communities as networks of promoters, redefining innovation communities as "An informal network of like-minded individuals, acting as universal or specialised promoters, often from more than one company and different organisations that team up in a project, and commonly promote a specific innovation, either on one or across different levels of an innovation system."

Based on the framework mentioned above, the case study set out to analyse the community created around the OxyGEN project and its participation in developing and disseminating this innovation.

## 3. Methods

### 3.1. Case study methodology

This research used the case study methodology to document and analyse the OxyGEN emergency ventilator's development during the first wave of the Covid-19 pandemic. First, we describe Protofy, the firm that led, accelerated, and developed the project, followed by the context of the Covid-19 outbreak in Spain. Then, we recount the design and development of the Oxygen emergency ventilator itself and finally describe the innovation community built around the project, which played a crucial role in its manufacturing and global distribution.

The case study method was chosen for its suitability for showing how open hardware and the open innovation approach combined to drive innovation forward. As Yin (2009a) remarks, one of the strengths of the case study research methodology is that it provides a rich contextual analysis of the unit of study, at a qualitative detail that cannot be replicated using quantitative or experimental methods.

## 3.2. Data collection

The primary data sources for this case-study are interviews, surveys, and documental review. Interviews were conducted with the co-founders of Protofy to discuss their perspectives and experiences. We used a semi-structured format for this interview. The interviews were recorded and transcribed to assist in the analysis.

We applied the surveys in the second half of April, during the lockdown. The criterion for selecting the sample subjects (project/team leaders) was the completion of a self-administered questionnaire, through the Google Forms application (online), due to its flexibility and suitability to adjust to the needs of the research for free and without limitations (Abundis, 2016).

The questionnaire consists of 12 questions divided into three sections: general information about the project and team profile, degree of involvement in the OxyGEN project, and cooperation with partners in their respective countries.
Annex 1 shows the questionnaire applied to the OxyGEN community.

The questionnaire's link was sent to all OxyGEN community members registered on Discord.com, the team members' platform to communicate and share relevant information for each project's development. The response level reached 62%, which corresponds to 30 projects/teams worldwide.

Relevant company documents were also analysed. These included the blog, video journal, tutorials, publications in newspapers and magazines, the project's dedicated website, and participating partners' publications.

An active dialogue was maintained with Protofy to clarify inconsistencies and expand and develop the data. In the case of study research, by collecting and cross-examining data about the innovation process from multiple sources, data collection and interpretation are likely to be an accurate representation of reality (Yin, 2009b).

# 4. The OxyGEN Project

## 4.1. The company

Protofy is a company based in Barcelona, specialized in the design, engineering, and rapid prototyping of creative and innovative ideas. Protofy prides itself on its agility and its ability to work in close collaboration with its customers and stakeholders.

The company was created in February of 2016 by a multidisciplinary team of young engineers committed to quality, safety, and technology. The team currently consists of seven people, equipped with the knowledge, tools, and talent to design all kinds of electronic circuits incorporated and mechanical parts, Internet of Things (IoT) development, and software development for both desktop and mobile devices.
Protofy's service includes all development stages, from idea generation, testing, prototyping, and redesign of iterations. They aim to integrate hardware (mechanics, electronics, electricity) and software to provide high-quality technological solutions.

This small but knowledge-intensive company stands out for its speed to carry out the projects, between three and six weeks. According to Lluis Rovira, co-founder, this is due to the use of project tools such as lean and scrum, which let them plan and develop projects as design iterations validated by the clients and users. Protofy also has a distinctly developed capacity to create collaboration networks with suppliers and other market participants.

## 4.2. The problem

The first imported Covid-19 case in Spain was dated January 31, 2020, in the Spanish Canary Islands. One month later, on February 25, 2020, the first case was reported in the Spanish peninsula. However, Covid-19 cases were likely circulating in Catalonia before the official cases were reported (Coma et al., 2020). As Covid-19 confirmed cases grew exponentially, on March 30, a national lockdown was declared, and all non-essential activities were suspended.

By April 4, Spain had become one of the worst-hit countries by the pandemic. The number of infected rose to 124,736 cases, 57,612 were hospitalized, and 11,700 deceased (Department of National Security DNS, 2020). The number of patients admitted to ICUs reached 3078 cases (Spanish Ministry of Health, 2020). According to the Spanish Scientific News Agency SINC (2020), between 10% and 15% of patients admitted to hospital with pneumonia caused by Covid-19 are admitted to the ICU, 90% of which require intubation and mechanical ventilation, generally for at least two or three weeks.

Thus, one of the most challenging problems to face during the pandemic was the sudden lack of ventilation equipment in intensive care units. With the international markets undersupplied and countries outbidding each other for equipment, locally developing and manufacturing ventilators became the most viable, if not the only option for Spain and many other countries.

## 4.3. The OxyGEN Ventilator

According to the interview with the founders of Protofy, what motivated them to carry out the OxyGEN Project was to contribute with their knowledge to solve the problem of the insufficient number of mechanical ventilators in the local hospitals to avoid loss of life, and to some extent also try to help alleviate the situation in remote small towns or less developed countries. Thus, their team of engineers set out to design a low-cost emergency ventilator that would be easy to build, with available materials that could be easy to find amid curfews and nation-wide lockdowns.

The team began looking for the technical requirements for the ventilator design and found valuable information shared by other experts who were also working around the world. In particular, MIT's emergency ventilator design toolkit proved useful to the team, and Protofy's design was eventually featured on MIT's website.

Very early, the team also adopted the Open-hardware strategy to carry out the project. They decided to create a dedicated website to document their journey, share information about the project, and make their design available to download by interested builders worldwide. The decision to create a dedicated website and publish it both in English and Spanish proved to be pivotal, as search engines eventually indexed and gave their site great exposure, especially in Spanish-speaking countries.

The team had to overcome lockdown restrictions to procure the first set of pieces and materials, but they moved quickly with creativity and teamwork. They tapped into their network for expert advice when needed and created a community workspace, also known as "server" on Discord.com, where they could communicate, share information, and problem-solve about the project more effectively with people from their network, as well as visitors to the project's website. In a record time of three days, the team built the first version of the volume-controlled ventilator in wood with two innovative features: a) The use of a Bag Valve Mask Unit (BMV), also known as Ambu bag or manual resuscitator. A standard piece of medical equipment used for patient ventilation in ambulances and b) A retrofitted windshield wiper motor to provide compression.

After a series of iterations, the team decided to separate the design into two versions: a) OxyGEN-M, which can be made at makers' facilities using wood or methacrylate; and b) OxyGEN-IP, an industrial model in sheet metal, designed for mass-production.

Further into the design process, they sought scientific support from the Hospital and Research Institute Germans Trias and Pujol (IGTP) and the Faculty of Medicine and Health Sciences of the University of Barcelona. The hospital's involvement during ideation brought medical expertise and credibility into the project. It is worth noting the absorptive capacity of the hospital staff. Interviewees commented that one of the medical doctors happened to have an engineering degree, which created a natural affinity with their team.

Under the supervision of the medical personnel of the hospital, they carried out all the clinical trials. On March 30, 2020, they obtained a special authorization from the Spanish Ministry of Health (AEMPS) for the OxyGEN model-IP to be used in patients.

Finally, SEAT, a Volkswagen subsidiary, carried out the OxyGEN-IP model's mass-production at their Martorell factory. For this, they modified some of its vehicle assembly lines to assemble the electronic and mechanical components, among them the adapted motor of the windshield wiper, performing an exhaustive quality control with ultraviolet light sterilization. More than 150 employees participated in production to attend to the needs of health care centers. In total, 600 OxyGEN ventilators were produced. Equivalent to 20% of the projected demand in Spain for emergency respiratory equipment due to the Covid-19 outbreak. More than 15 enterprises among suppliers, hospitals, universities, research institutes, and authorities cooperated in carrying forward the OxyGEN project in Spain. Inspired by their success, other Volkswagen subsidiaries from Brazil and Eastern Europe followed suit and produced Oxygen ventilators for their countries.

## 4.4. The OxyGEN Community

The OxyGEN community is made up of 241 active members distributed in 47 teams in 32 countries. On average, there are five members in each group. Most of the teams (53%) belong to the Americas, 19% to Europe, 15% to Asia, and 13% to Africa. Table 1 shows the OxyGEN community members' distribution.

| Continents | Countries | | Teams | | Members | |
|---|---|---|---|---|---|---|
| | N | % | N | % | N | % |
| America | 13 | 41% | 25 | 53% | 150 | 62% |
| Europe | 8 | 25% | 9 | 19% | 45 | 19% |
| Asia | 7 | 22% | 7 | 15% | 28 | 12% |
| Africa | 4 | 13% | 6 | 13% | 18 | 7% |
| Total | 32 | 100% | 47 | 100% | 241 | 100% |

Source: https://www.oxygen.protofy.xyz/community. Own elaboration.

**Table 1.** OxyGEN Community members.

The community teams are multidisciplinary. They are made up of engineers from different areas: industrial, mechanics, electronics, and computer science. About 26.32% of teams count with the support of doctors or health personnel; approximately 36.84% of teams count with designers, and another 36% are made up of professionals in other areas. Figure 1 shows the members' profiles of the teams.

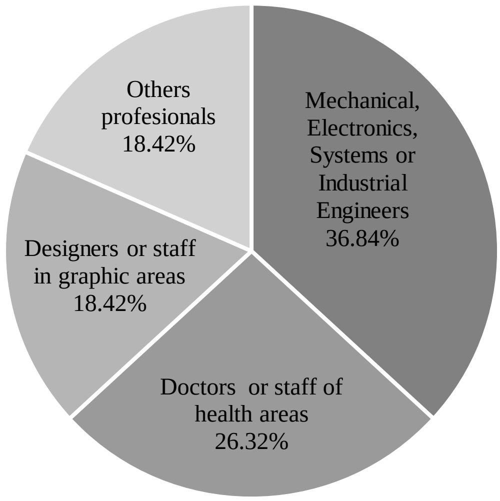


**Figure 1.** Profile of OxyGEN community members.

The OxyGEN community was formed very early in the project. Because of that, about 43% of teams collaborated directly in the design of the first OxyGEN prototype, but others joined quickly and learned from the experience gained to apply it to their projects. Once Protofy company released the manual for ventilator design and construction, 36% of community member teams directly adopted the design. The remaining 64% iterated on the design to develop their own derived version of the ventilator. Figure 2 shows the technology adoption.

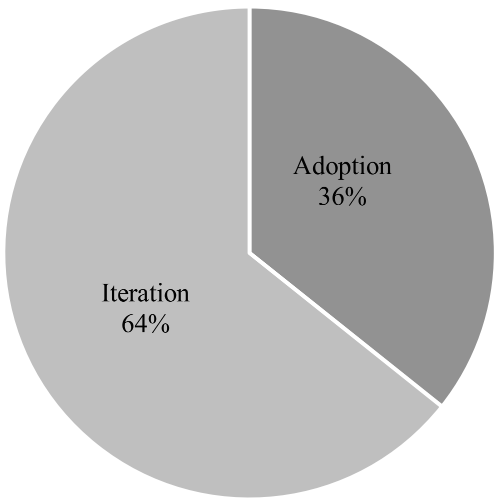


**Figure 2.** Technology adoption among members of the OxyGEN community

At the time of this study, 43% of the projects are in the prototyping phase, 38% are waiting for authorization from other entities or institutions, and 21% have reached the manufacturing stage. Figure 3 shows the status of the projects.

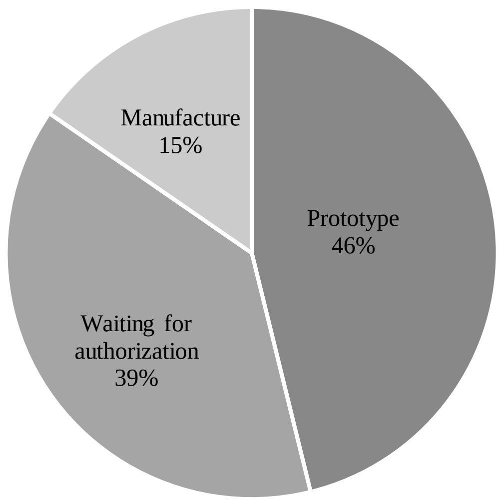


**Figure 3.** Status of projects in the OxyGEN community.

Most of the teams collaborated with suppliers of equipment, materials, components, and software inside the community (31%), consultants and laboratories outside of the community (27,6%), other teams in the OxyGEN community (17%), and the remaining 30% with universities or research institutes. Figure 4 shows the collaboration of the teams with different partners.

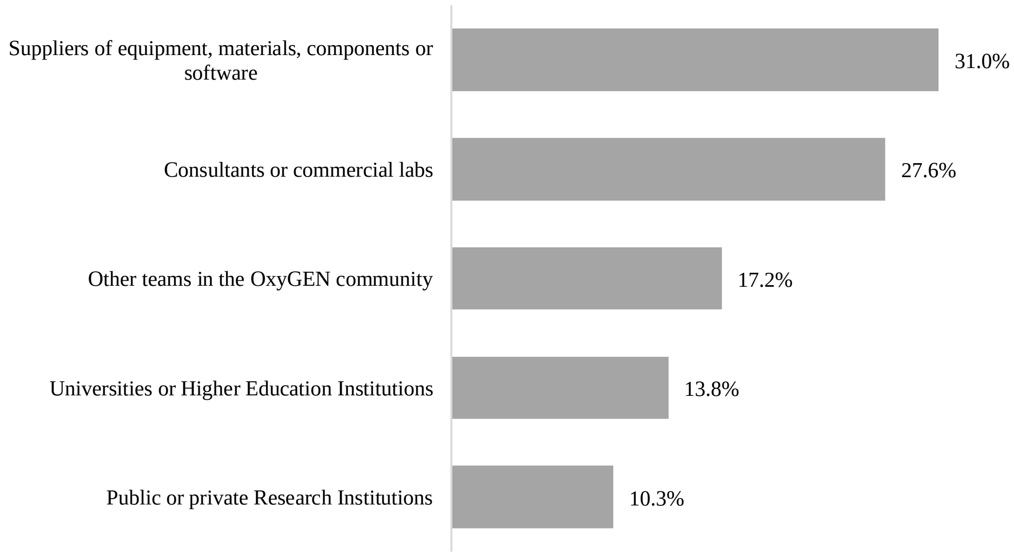


**Figure 4.** Collaboration partners

## 5. Discussion

According to the results, the characteristics and internal organisational practices of Protofy and the Project Oxygen community which enabled them to develop and carry out this innovation during the Covid-19 pandemic correspond to the three processes of open innovation: the inbound process, the outbound process, and the linking of inbound and outbound processes (Gassman and Enkel (2007).

### 5.1. Inbound Process

At the beginning of the process, Protofy had to find useful ideas and external information to develop their project. Nevertheless, the firm had well developed internal organizational practices for open inbound innovation already, which allow us to characterize it as a "full-scope searcher." Brunswicker and Vanhaverbeke (2015) point out that firms in this typology are heavily involved in knowledge sourcing, show a keen interest in external ideas from various sources, and have built an innovation ecosystem for new ideas. The number and diversity of Protofy's sources (researchers in universities, companies, or teams in the world who also had taken on the challenge of creating an emergency ventilator) are a straightforward exhibit of this profile.

The internal organizational practices observed implementing/supporting this innovation sourcing profile are:

1. Innovation strategy processes. Protofy used the open hardware strategy for the development of a low cost and quickly-to-assemble emergency ventilator. Precisely, some benefits of the open-source hardware are a significant source of good ideas, high participation of the community and a high level of transparency in the development process, a high development speed, often high modularity in their solutions, extraordinary development potential for free and a high level of continuous improvement (Merkel et al., 2012b). Niezen et al. (2016) point out that such advantages are particularly well suited for medical equipment production.

2. Innovation development processes. Protofy created an ecosystem to share ideas and solutions to develop the OxyGEN project collaboratively. The practice to document and make everything publicly available in different media formats and platforms, with

a particular preoccupation on how others can make use of their design or how they can be engaged in co-designing the prototype, was critical in building a community of co-innovators and promoters of the innovation.

3. Innovation project control. Protofy used agile project management methodologies to enable rapid prototyping. Well suited to the crisis, which demanded a fast response. Furthermore, workflows built around close and constant communication with customers translated well to dealing with Hospital staff to co-design the ventilator and work with stakeholders in a clinical trial and industrial settings.

4. Long-term investment activities. Protofy carried out the OxyGEN project motivated solely by its spirit of collaboration in the face of the health crisis. However, the activities carried out for the construction of a medical device successfully in such a short-time contributed to developing new knowledge and skills in the project's team. The company could exploit this investment of time and resources in new healthcare industry projects or others.

## 5.2. Outbound process

The inside-out (outbound) process occurred through the release of OxyGEN ventilator design so that other individuals, teams, manufacturers, or companies could take it and develop their projects. These individuals or firms became part of the community either by adopting or interacting with the technology.

This community of co-innovators and promoters of innovation played a fundamental role in developing and expanding this innovation to other countries. The community interactions with Protofy helped overcome the challenges intrinsic to developing medical technology, while support among the community members facilitated its adoption and use. The leadership of promoters and managerial skills aforementioned allowed Protofy to find complex solutions in a collaborative environment. Based on the results obtained of the survey to the OxyGEN community, below we point out the characteristics beyond the firm level that facilitated the adoption/iteration of the technology:

1. Multidisciplinary teams. This characteristic allows them to find rapid solutions to complex problems or situations.

2. Collaborative technologies support effective communication. They enabled real-time communication, mutual support and allowed massive exposure.

3. Open access to knowledge and information. The pandemic created the conditions for the practice of open innovation to become widespread. This climate of willingness to cooperate in response to the pandemic was further facilitated by using the Creative Commons Licence, which removed legal barriers to involving enterprises such as car manufacturers. In Canada, for instance, car manufacturing companies willing to collaborate with medical technology firms also emerged in response to the pandemic. However, the collaboration did not occur to the same degree due to legal concerns (Globe and Mail, 2020).

4. No language barrier. The community quickly became populated by members from different nationalities, who, in turn, facilitated access to the technology by people from non-English speaking countries.

5. Low level of competition. Developing countries found themselves unable to compete in international markets to acquire the necessary medical equipment during the pandemic, nor did they have local companies to manufacture such equipment. This issue could explain the predominance of teams from developing countries and the absence of teams from advanced economies.

6. Network effects. The initial collaboration with all types of local partners: suppliers, consultants, or commercial laboratories, universities, and research institutions, in turn, fostered the involvement of similar institutions in other countries.

## 5.3. Linking of inbound and outbound processes

Protofy moved to established alliances with relevant and complementary companies to advance the development and adoption of the OxyGEN Ventilator. The GTP Research Hospital and SEAT, most notably, were the partners whose involvement in the project had the most transformative effect. Partnership with the Research Hospital resulted from Protofy's initiative; however, SEAT's participation came about due to the prior relationship with that company, which had hired Protofy in the past. Acquiring knowledge through the partnership with the Research hospital, while recasting SEAT to make use of one of their designs once again, demonstrates this firm's ability to link inbound and outbound processes to advance their purpose.

## 6. Conclusions

This case study set out to describe and analyse the OxyGEN Project from the perspective of Open Innovation. In response to the health crisis caused by the Covid-19 outbreak, Protofy, a Barcelona-based design company, led this project, which prototyped, developed, mass-produced, and distributed an industrial-class emergency ventilator to hospitals worldwide by creating an innovation community around the project. Protofy pursued this project with non-profit motivations, yet it provides a useful example of how open innovation strategies and building innovation communities can reduce time to market and increase technology adoption rates.

For this innovation project's design and development, the company directed its efforts to search for external sources of knowledge through cooperation with clients, suppliers, universities, and research centers. In other words, adopted an inbound open innovation process. Also, it deployed its ability to create an innovation community, combining an outbound open innovation process with an open hardware strategy, following the trend of companies adopting practices and values of the open-source movement to advance technological development and project goals.

The organizational practices observed and the strategies adopted by the company also allowed us to characterize Protofy as a "full-scope searcher." Brunswicker and Vanhaverbeke (2015) define firms in this typology as those which are: heavily involved in knowledge sourcing, show a keen interest in external ideas from various sources, and have built an innovation ecosystem for new ideas. Protofy's example, in particular, shows how firms who adopt a full-scope searcher innovation strategy can respond quickly to dramatic change.

The Oxygen community played a dual role in the project's development, as co-creators and promoters of this innovation. As Von Hippel (2006) points out: "Democratization of the opportunity to create is important beyond giving more users the ability to make exactly the right product for themselves. The joy and the learning associated with creativity and membership in creative communities are also important". It was this sense of community the main factor which channeled international enthusiasm into action. This factor, which combined others mainly: the teams' multidisciplinarity, collaborative tools to support remote work and effective communication, and a climate of openness for inter-organizational partnerships, resulted in a remarkable response to the Covid-19 pandemic.

For academics, this case study provides an example of open innovation in the crisis and inter-organizational collaboration between firms of different sectors (industries and services) with universities and research institutes. In particular, evidencing how knowledge-intensive business services (KIBS) cooperate with research institutions to receive scientific support and apply knowledge transfer for innovation. (Lee and Miozzo, 2019).

For companies, this case highlights the importance of community-building and developing internal capabilities to co-create with innovation communities. As a way to adopt external knowledge sourcing strategies and take advantage of open innovation.

Policymakers may use this case study to support the streamlining of approval processes for medical equipment and policies to promote public-private research projects.

The main limitation of a case study is that it cannot be generalised but allows digging into how and why questions. In that sense, further empirical research could analyze a sample of industries and services that used open-source values and strategies to innovate during the pandemic. Furthermore, future research could be performed regarding firms that reinvented themselves, innovated their products or services using collaborative tools during the pandemic. Also, to investigate the effects of the new forms of work enabled by these technologies on their organizational structure.

## REFERENCES

Bianchi, M., C. Orto, S. and Vercesi, P. (2010). Enabling open innovation in small and medium-sized enterprises: How to find alternative applications for your technologies? *R and D Management*, 40, 414–431.

Benner, M.J. (2009). Dynamic or static capabilities? Process management practices and response to technological change. *Journal of Product Innovation Management*, 26, 473–486.

Brunswicker, S. and Vanhaverbeke, W. (2015). Open Innovation in Small and Medium-Sized Enterprises (SMEs): External Knowledge Sourcing Strategies and Internal Organizational Facilitators. *Journal of Small Business Management*, 53, 1241–1263.

Chesbrough, H. (2006). Open Innovation: A New Paradigm for Understanding Industrial Innovation, in Chesbrough, H., Vanhaverbeke, W., West, J. (Eds.), *Open Innovation: Researching a New Paradigm*. Oxford: Oxford University Press.

Chesbrough, H. and Crowther, A.K. (2006). Beyond high tech: Early adopters of open innovation in other industries. *R and D Management*, 36, 229–236.

Coma, E., Mora, N., Prats-Uribe, A., Fina, F., Prieto-Alhambra, D., and Medina-Peralta, M. (2020). Excess cases of influenza suggest an earlier start to the coronavirus epidemic in Spain than official figures tell us: an analysis of primary care electronic medical records from over 6 million people from Catalonia. *medRxiv*, 2020.04.09.20056259.

Department of National Security DNS. (2020, April). Coronavirus (COVID-19). Retrieved from https://www.dsn.gob.es/en/actualidad/sala-prensa/coronavirus-covid-19-04-abril-2020.

Fichter, K. (2009). Innovation communities: The role of networks of promoters in open innovation. *R and D Management*, 39, 357–371.

Gassmann, O. and Enkel, E. (2007). Towards a theory of Open Innovation: three core process archetypes. *Proceedings of the R&D Management Conference*, Lisbon, Portugal.

Goffin, K. and Mitchell, R. (2005). *Innovation Management: Strategy and Implementation Using the Pentathlon Framework*. Houndmills, Basingstoke: Palgrave Macmillan.

The Global and Mail. (2020, April). Emergency coronavirus bill could help auto parts firms retool to produce ventilators. Retrieved from https://www.theglobeandmail.com/politics/article-emergency-coronavirus-bill-could-help-auto-parts-firms-retool-to/.

Lakhani, K. R. and von Hippel, E., (2003). How open-source software works: free user to user assistance, *Research Policy*, 32(6), 923–943.

Lichtenthaler, U. (2009) Outbound open innovation and its effect on firm performance: Examining environmental influences. *R and D Managemen*t, 39, 317–330.

Merkel, A., Hopf, H., and Müller, E. (2012). Accelerating the Innovation Process with the Help of Open Source Prototyping Hardware. Annals of the Faculty of Engineering Hunedoara. *International Journal of Engineering*, 10(1), 105–112.

National Center for Epidemiology CNE. (2020, April). Informe nº 21. Situación de COVID-19 en España a 6 de abril de 2020. Retrieved from https://www.isciii.es.

Nelson, R. and Winter, S.G (1982) An Evolutionary Theory of Economic Change. Cambridge (Massachusetts), London: Harvard Business School Press.

Niezen, G., Eslambolchilar, P., and Thimbleby, H. (2016). Open-source hardware for medical devices. *BMJ Innovations*, *2*(2), 78–83.

Olson, J.S. and Olson, G.M. (2013). Working together apart: collaboration over the internet. *Synth Lect Hum Center Inform*, 6(5), 1–151.

Parida, V., Westerberg, M. and Frishammar, J. (2012). Inbound Open Innovation Activities in High-Tech SMEs: The Impact on Innovation Performance. *Journal of Small Business Management*, 50(2), 283–309.

Robertson, P. L., Casali, G.L and Jacobson, D. (2012) Managing Open Incremental Process Innovation: Absorptive Capacity and Distributed Learning, *Research Policy*, 41(5), 822–832.

SINC Agency. (2020, April). Así están trabajando las UCI en el centro de la tormenta de la COVID-19. Retrieved from https://www.agenciasinc.es/Opinion/Asi-estan-trabajando-las-UCI-en-el-centro-de-la-tormenta-de-la-COVID-19.

Van de Vrande, V., de Jong, J.P. and de Rochemont, M. (2009). Open innovation in SMEs: Trends, motives and management challenges. *Technovation*, 29, 423–437.

Von Hippel, E. (2001). Open source shows the way: innovation by and for users no manufacturer required, *Sloan Management Review*, 42(4), 82–86.

Von Hippel, E. (2005). 'Innovation Communities,' in von Hippel, E. (ed.) *Democratizing Innovation*. Cambridge, MA: The MIT Press.

West, J. and Lakhani, K.R. (2008). Getting Clear About Communities in Open Innovation, *Industry and Innovation*, 15(2), 223–231

Tidd, J. (2001) Innovation management in context: Environment, organization, and performance. *International Journal of Management Reviews*, 3, 169–183.

Yin, R.K. (2009). Case Study Research: Design and Methods, 4th ed. Thousand Oaks CA: Sage Publications.

Von. Hippel, E. (2005). *Democratizing Innovation*: The MIT Press.