July 2022

Proposal for a Cooperative Model for Digital Infrastructure and Recommendations to Adopt It

Cooperativa Tierra Común

contacto@tierracomun.org

Table of Contents

1. Introduction

Digital infrastructure such as source code libraries, frameworks and software tools for programming are crucial for the operation of millions of internet sites, services and platforms. Many digital infrastructure projects (DI from here on) lack an organizational structure that allows them to be sustained over time. This is because these projects have difficulties in accessing economic, material and information resources to sustain themselves. The objective of this research is to investigate whether cooperatives are a type of organization that can support DI and if there are cooperatives that support DI, how they achieve it. Once learning about the development and maintenance of DI that cooperatives do, a cooperative model is proposed to support DI that serves as a reference for DI projects that wish to form their own cooperative. Based on the research findings, recommendations are provided that help follow this model.

2. Problem Formulation

Digital infrastructure such as source code libraries, frameworks and software tools for programming are crucial for the operation of millions of internet sites, services and platforms. Many digital infrastructure projects (DI from here on) lack an organizational structure that allows them to be sustained over time. This has to do with the fact that these DI projects have difficulties in accessing economic, material and information resources to sustain themselves, such as: financing, stable income for their contributions, infrastructure, strategic alliances, etc. Some of the specific needs that previous DI research have identified are lack of: planning, workflows, diversity of skills that support and complement technical programming tasks, exchange of knowledge with the user community, etc. (Eghbal 2016).

For their part, cooperative organizations have historically provided essential goods and services through sustainable resource management and in recent years have demonstrated their ability to maintain complex technological infrastructure such as solar and wind power distribution (Šahović y da Silva 2016). However, there are not enough empirical studies on this, especially regarding cooperatives that support DI. As we will demonstrate in the findings of this research, not only are there cooperatives that develop software (CICOPA 2017), but there are currently cooperatives that are producing and maintaining DI.

Having knowledge about the above and knowing how cooperatives support DI is important because the different fundraising options that have been tried such as donations, crowdfunding and bounties are temporary and may not be enough for all cases. However, the fact that a democratic organization such as cooperatives may manage and help sustaining DI has not been explored. Since cooperatives are organizations with both market but also community orientations and essential to the social and solidarity economy (Dilger, Konter, y Voigt 2017), they can uniquely contribute to sustaining DI, preserving the distributed nature of free and open source software (FLOSS from now on), the spirit of collaboration and close relations with the community of users and developers, as well as integrating democratic practices and participation in the maintenance of public resources such as DI. This is why it is essential to better understand how the cooperatives that already develop and maintain DI have done it, and to get from their experience a model and recommendations that projects without an organizational structure can follow.

¿What is known about the problem?

In its 2016 report, the International Organization of Cooperatives in Industry and Services (CICOPA) published that 2,063 cooperatives provided Information and Communication Technology services (ICT) and considered that this was a growing trend, especially in countries such as Argentina, Uruguay, United Kingdom, France, Italy and Denmark (CICOPA 2017).

Although ICT services provided by cooperatives are very diverse, not all of them account for the production and maintenance of DI. However, an initial approach to cooperatives working in this sector can be made with an intensive search on dedicated websites, online forums and social media channels. For example, a direct evidence of this is coophub.io.[1] Coophub is an open FLOSS repository, which includes software tools, components, modules, and libraries developed by more than 50 cooperatives located in countries such as Argentina, Brazil, the United Kingdom, Canada, and the United States. Although not all code on Coophub qualifies as DI, some of the most popular repositories have hundreds of contributors and thousands of commits. The most impressive example is the Go Free Range worker cooperative Mocha library which has over 4400 dependent

1 https://coophub.io

packages. Although comprehensive global statistics of cooperatives working on DI are not available, Coophub was the starting point of our research and we subsequently continued with a more intensive search for more cooperatives producing and sustaining DI.

On the other hand, in economic studies it is common to use business models that adhere to the theories of conventional economics. However, these models do not fully correspond to a particular type of economic organization such as cooperatives. This is due to the duality of objectives to which cooperatives may be oriented, which can be aimed at both market efficiency and for the benefit of the community. This is why a specific business model for cooperatives must include both orientations. Dilger, Konter and Voigt in their article *Introducing a Co-Operative-Specific Business Model: The Poles of Profit and Community and Their Impact on Organizational Models of Energy Co-Operatives* propose three cooperative models that represent reference positions in a spectrum. These range from cooperatives that are purely market oriented to cooperatives that are purely community oriented, including a hybrid model in between. The authors test the cooperative model by examining the sustainability of renewable energy distribution infrastructure provided by cooperatives. However, due to the differences between the electrical infrastructure and DI —the main difference being the distributed development and maintenance of the code— it is necessary to propose the following principles to address them in the model that will be proposed in this research.

Thanks to the initiative of programmers, it is important to take into account that these projects are built "from the bottom up", as described in Nadia Eghbal's metaphor: "*It is akin to a group of citizens getting together and deciding they want to build a bridge or create their own sewage system*", and precisely like this is how cooperatives have historically dedicated themselves to provide for the insufficiencies in the supply from the market and the State in the provision of varied public goods and services (Spear 2000). This is why the following design principles, strategies and critical areas that require support were suggested in the Roads and Bridges report (Eghbal 2016) and will be addressed in the proposed cooperative model:

- Adopt distributed development;
- Work closely with existing software communities;
- Consider a holistic approach to project support;
- Help project maintainers plan ahead;
- Treat digital infrastructure as a public good;
- Work to improve workflows;

- Expand the group of collaborators

Finally, it is worth clarifying that although the benefits that cooperatives can offer DI, and although working in a cooperative that develops software involves many challenges, not all the administrative and technical problems of a cooperative will be addressed here. Neither is the objective of this research to evaluate the work done by the cooperatives studied or investigate how other non-cooperative companies sustain DI.

3. Purpose and Research Question

The purpose of this research is to know how cooperatives produce and sustain DI so that projects that do not yet have an organizational structure adopt the cooperative model and this helps them sustain their DI. This is why this research seeks to answer two central questions.:

1. How do cooperatives produce and sustain DI?

and

2. How can DI projects adopt the cooperative model for sustaining DI?

Therefore, the objectives are:
1. Obtain a specific cooperative **model** for DI that reflects what we know about the work that cooperatives already do with DI.
2. Formulate **recommendations** to form a cooperative that develops DI based on the proposed model.

The working hypotheses from which we start are that cooperatives:
1. Direct their objectives towards both the market and the community this benefits DI projects.
2. They provide decentralized production of DI.
3. They satisfy DI requirements that not only have to do with code such as planning and workflows, as well as other essential tasks by integrating people with diverse knowledge and skills to support DI.
4. They take into account the beneficiaries of the DI in the production of its value chain.
5. They promote democratic practices in the production and maintenance of DI.

4. Research Paradigm and Qualitative Approach

The qualitative approach has been designed out in three stages to explore, expand and deepen the knowledge of the activities carried out by cooperatives that produce and maintain DI. First, the starting point was the study of public repositories and online documentation of cooperatives through the analysis and coding of documents, taken into account as the empirical evidence collected on the internet of this activity. Second, to expand and verify this information, an online survey was designed for the cooperatives that we found with the sampling that produce and maintain DI. And third, to have more depth a focus group was made with the members of cooperatives that develop DI and thus learn from their first-hand experience about the work they do. The final analysis was carried out following a practical approach so that the results serve to provide a useful model and specific recommendations for DI projects.

5. Sampling Strategy

The non-probabilistic sampling strategy consisted of intentionally looking for DI projects that are developed by cooperatives. For this, it was first necessary to determine the characteristics of a DI project, and second, search the cooperatives' online code repositories for software projects that met these characteristics, since not all the software developed by cooperatives is DI.

The characteristics of a Digital Infrastructure project are:

• Code available on the internet that must have **FLOSS** licenses.

• Code that have package or repository **dependencies**, or

• Contributors to the code from the cooperative but also from developers that are **external** to the cooperative.

This is essential because FLOSS code is "*open source code that can be used by anyone—from companies to individuals—to build software*" (Eghbal 2016), fundamental feature for the DI to be public. Likewise, the dependence of packages or repositories that is shown in some repositories such as Github is important,[2] because this means that there is other

2 About the dependency graph.

software that uses this code forming the basis of a larger system. However, as the Github documentation indicates, not all dependencies are always shown, as this information has to be provided correctly by the developer.[3] This is why it was also taken into account that other developers outside the cooperative contribute to the code since this indicates that the code is not used only by the cooperative, but that there are other developers outside that use it and benefit from it and therefore contribute to its maintenance and improvement.[4]

The initial sample was provided by the Coophub web application of the Argentinean cooperative Fiqus. Coophub is a website that showcases Github-hosted software developed by cooperatives. This gave the initial population, from which the most popular repositories were examined for their highest probability of meeting the characteristics of being DI (FLOSS, with dependencies and/or with external contributors). The result of this first sample was 9 DI projects developed by 9 cooperatives.[5] To determine that they were in fact cooperatives, it was sufficient that they had a .coop domain,[6] that they indicate on their website their legal registration as a cooperative or that they show that they belonged to a federation of cooperatives. To achieve greater variation, the search was expanded to repositories on platforms other than Github, such as Gitlab.com, the Drupal module repository, and repositories hosted by the cooperatives themselves. In this way, another 12 DI projects developed by **12 cooperatives** were found. Giving a total of **21 DI projects**. Sampling stopped when no more projects were found that met the DI characteristics.

We did not include in the sample projects that were not developed by cooperatives, or cooperatives that, although they provide internet infrastructure at the closing date of the sampling, have not published their code as FLOSS in repositories for public use where developers who do not belong to the cooperative contribute to. In other words, the criterion for this sampling is based on the definition we propose of digital infrastructure, where there is a dependency on the infrastructure that developers external to the

---

3 "If your dependency graph is empty, there may be a problem with the file containing your dependencies. Check the file to ensure that it's correctly formatted for the file type." Troubleshooting the dependency graph.

4 In these cases, it was confirmed by triangulating the information on the websites of the cooperatives and the developers that contribute to the code.

5 Some cooperatives have more than one DI project and in other DI projects more than one cooperative collaborates.

6 To obtain a .coop domain, providers require the applicant to prove through legal documents that they are a cooperative.

cooperative have in the direct use of the code that is the DI itself,[7] and not the dependency of developers of the cooperative on their own code,[8] or end users in applications packaged and made available as a finished product or service. The cooperatives that have their repositories online but in which the collaboration of other external developers or users in the commits or issues is not shown, or that it is not apparent that the code is used in another development project that is not of the same cooperative, have not been included.

6. Ethical Issues

Although the researchers are members of the technology cooperative Tierra Común, we do not have a business relationship with any of the cooperatives investigated and our cooperative is not included in this research. In addition, to avoid some of the biases that we can have as people who promote cooperatives and in order to ethically and methodologically monitor the proper development of this research, the cooperative hired a researcher who served as a consultant to the process and who is not part of the cooperative movement. The consultant has the appropriate profile and sufficient experience and had permanent access to the research project, the methods, instruments and data that were processed, guiding the development of the research and making suggestions that were taken into account and integrated into the research.

7. Data Collection Methods

The type of information collected consisted of all the evidence that indicated the activities that the cooperatives carry out that have to do with the development and maintenance of DI, such as programming, technical support, documentation implementation, promotion, training, managing, planning, etc.

7 For example, to be included as part of a larger code and development or for projects other than those carried out by the same cooperative.

8 Internet repositories are not necessarily used for open collaboration, but in some cases as a way for a group belonging to the same organization to work on their code to use version control or as backup, without allowing external developers to contribute. In other words, having a code repository on the internet does not necessarily mean that it is already a tool that by itself allows others to collaborate on it.

Three methods were applied (document analysis, online survey and focus group) that complemented each other to obtain more robust results. The exploratory document analysis of the 12 cooperatives that do DI, the online survey to have breadth and precision with responses from 11 cooperatives distributed in different countries and the focus group to deepen the understanding of the experience to sustain DI in which members of 4 of these cooperatives participated.

Document analysis: Since the cooperatives develop and maintain the DI in a distributed way, publish the code and document their projects on the internet, the first step was to search online for information about these activities already made available to the public by the cooperatives themselves and systematize it. Then in order to leave for the survey and the focus group details that were not already in published documents or were not clear, confirmation, triangulation and deepened understanding was made with direct contact with the members of the cooperatives themselves through the other instruments. This first stage of review, systematization and analysis of documents was carried out between April and August 2021, although this was revisited in the iterative process of the research to corroborate or contrast the information obtained with the other instruments in the subsequent months.

Online survey: The survey was sent to all the cooperatives that we found with the sampling that make DI and was composed with both open and closed questions. The questions were asked so that the participants could provide data on the activities carried out by their cooperative around software development and DI and other questions to obtain the opinion of the members of the cooperatives who answered. In addition, some demographic questions were included to know the professional profiles of the participants. The objective of the survey was to know more specifically the activities directly related to the programming and maintenance of DI, as well as to know the activities not directly related to programming but that also help sustain DI, in addition to other types of resources that cooperatives contribute to this activity. It also included questions about the division of labor and organization of the cooperative, and decisions and workflows. In addition, the survey was used to expand and verify the information obtained with the documentary analysis. The survey was open between December 2021 and March 2022.

Focus group: To delve into the above, a focus group was held with the participation of 4 members of 4 cooperatives that develop and maintain DI and thus learn first-hand the experience of these cooperatives in such activity and the relationship between cooperatives and development of DI. The group discussion was conducted in a controlled

manner, opening with general questions about "the ideal cooperative", followed by a more structured discussion around the "dilemmas" that a cooperative that develops software may face. The focus group was not planned for the group to reach a definitive consensus on all the topics discussed, but first, the intention was to motivate the group discussion on the advantages, disadvantages and problems that a cooperative that develops DI faces, and second, to know both the coincidences as well as the differences of opinion regarding their activity.[9]

Regarding the adjustments to the procedures prior to executing the survey and the focus group, we made modifications thanks to the information collected from two pilot interviews to probe that the questions were clear and pertinent. The dynamics of the focus group was adjusted so that it was not only appropriate for a cooperative in general that could be dedicated to any activity, but issues were included according to the problems that infrastructure projects have already defined previously in the research's problem formulation.

In summary, the three instruments were designed to: 1. Explore and approach the activities of cooperatives that develop and sustain DI using document analysis of information available on the internet. 2. To learn about a diversity of cooperatives and the variety of ways of work that cooperatives from different countries can have when developing DI, the online questionnaire was used. And 3. To delve into the experience of these cooperatives and their relationship with the problems of development of infrastructure, this is why the focus group was made.

8. Data Collection Instruments

Documentary analysis: The categories used for document analysis were divided between two researchers so that each one reviewed the documentation of each selected cooperative from the sample so that there was no variation between the criteria about the analytical categories that each researcher reviewed. Some of the categories used were: worker-members, clients and users, interactions with the community, value chain, among others. At the end, the two researchers shared the notes of each category so that

9 It was tried that at least one woman member of one of these cooperatives participated in the focus group, however we did not receive a response to the invitation that was made.

they could review them and know the analysis made of all the categories. These documents were shared so that the researchers could continuously refer to.

Online survey: It consisted of a questionnaire done with the Lime Survey web application; in English for cooperatives located in English-speaking countries and the same questionnaire in Spanish for cooperatives located in Spanish-speaking countries. The questionnaire consisted of 30 questions in total that were verified by a consultant in mixed research methods prior to circulation. When inviting the participants to fill it out, they were notified that it would not take more than 40 minutes to answer it so that they reserved enough time to respond to it and they were asked to please circulate it among the members of their cooperative. The survey remained open for 4 months, giving participants time to respond and reminders were sent when we did not get a response, which helped to achieve greater participation.

Focus group: The group discussion was conducted in a controlled manner, opening with general questions about "the ideal cooperative" followed by a more structured discussion around the "dilemmas" that a cooperative developing DI may face. To motivate and guide this last discussion, a dynamic was made in which the group participants ordered 7 elements about the ideal cooperative, ranking phrases by importance that combined the 7 cooperative principles with the needs of DI projects; resulting in the fundamentals that an ideal cooperative should have according to the participants.

The instruments for the focus group consisted of a guide with the questions and topics to be discussed proposed by the consultant and adjusted by the main researcher to increase the relationship of the questions with the working hypotheses on cooperatives and DI. This guide was translated into a script detailing the timing of each part and the technical procedures for executing the focus group. This was previously practiced by the team that carried out the focus group. The team consisted of the moderator, a colleague in charge of recording the video and audio of the session and the principal investigator who took notes during the session. When executed, the focus group lasted a total of two hours and fifteen minutes. Those who participated in the session signed a consent form and were later given a stipend or, if they preferred, a donation to the free software project of their choice.

9. Units of Study

To approach the object of study, two main units of study were defined and these are their characteristics:

Digital Infrastructure: The DI selection consists of 21 software projects to which 12 cooperatives contribute to. Among the types of DI, we find: libraries, tools, frameworks, modules, an API, a protocol and even time management and billing platforms, as well as the distribution of a CMS; written in different languages like Ruby, PHP, Python, Javascript, Shell, Go, HTML, CSS, etc. All projects are licensed under FLOSS, either the GNU General Public License or compatible with it.[10] The first of these projects started in 2008 and the most recent in 2019. The most distant last update of any of them is from 2018, but most have their last update in 2021 or 2022, which indicates that most of the projects are still active and in progress. The repository with the most contributors has 296 with 4,373 commits and the one with the least 3 with 24 commits until the closing of the sampling.

Cooperatives: Members of 11 cooperatives that develop DI participated in the study.[11] These cooperatives are established in Argentina (3), the United States (2), Spain (1), France (2) and Great Britain (3). The number of members that make up each cooperative varies from 4 the smallest to 47 people the largest at the end of the sampling. The cooperative with the longest existence was born in 2006 and the most recent in 2018.

10. Data Processing

Documentary analysis: The results of the documentary analysis were emptied into a database establishing relevant categories and relationships with the sampling between cooperatives and between DI projects, for example, classifying each of the activities around the DI that we found in the repositories and on their internet sites related to the software value chain. The categories of information already established by Internet repositories were also very useful to us, such as licenses, first and last commit, dependencies, releases, popularity, number of contributors, etc.

10 https://www.gnu.org/licenses/license-list.es.html#GPLCompatibleLicenses

11 We did not obtain answers from one of the cooperatives in the questionnaires, but we included it in the analysis of documents.

Online survey: The results of the online survey were processed as follows: First, the results of invalid responses were manually cleaned, such as those we received from cooperatives that do not develop DI or empty responses. Second, for the closed questions, the answers were ordered according to their repetition, thus establishing a numerical frequency for the answers among the different cooperatives. And third, the answers to the open-ended questions were grouped into similar themes and single answers that did not have any similarity with any other were discarded. In this way, an order of importance was established according to the repetition of the content of the answers, that is: as strong evidence for the most frequent answers and those that were least repeated as weak evidence, removing those that were unique and had no resemblance to any other answer. In the case of some answers that were not clear or from which sufficient certainty was not deduced, the answers were contrasted using the document analysis results and, if confirmed, they were kept for later analysis.

Focus group:

The recording of the focus group was made from two different devices in order to have two different files that could be verified between each other. The files were transcribed with NVivo Transcription. The transcript was later checked and corrected by two different researchers for accuracy.

11. Data Analysis

The data was ordered and classified according to categories given by the repositories, operationalizing them in correlation with the needs of DI projects. To achieve greater precision and detail and obtain the necessary elements for the model, a specialized method was used coming from the construction of specific software value chains. For this, the research *The Software Value Chain: Methods for Construction and Their Application* by Pussep et al. provides a clear distinction between the different activities of the software development value chain (Pussep, Schief, y Widjaja 2012). Thus, evidence of these activities was searched in the development of DI carried out by cooperatives.

12. Findings

Value Process and Value Chain

The fundamental elements of a business model consist of describing the process of creation, proposition and capture of value by those who intervene and are involved in the firm's activities, that is, not only by those who make up the firm but including those who the firm is involved in this process. In turn, this process breaks down into a set of distinctive activities that the firm carries out to create value and that it offers to its consumers in the form of products and services. For example the distinctive activities that have to do with logistics, production, marketing and sales, customer service, etc. This set of distinctive activities of a company is known as the value chain (Tardi 2022).

For its part, the production of FLOSS involves a group of people who collaborate with each other in a distributed manner in the development and maintenance of code without necessarily belonging to the same organization or company, since the code is public on the internet for anyone to use and contribute to its improvement. Thus, the provision of FLOSS occurs without necessarily depending on centralized hierarchies that vertically organize its production or directly by market price mechanisms that determine its supply and demand (Benkler 2017). This model of software development is known as peer production and although it does not necessarily require a company to organize it, there are companies that participate in the production of FLOSS and that combine the development model of peer production with their own business model (Morgan 2010).

To delve into the above, the set of distinctive activities that make up the software value chain are classified into primary activities, which are those directly related to the programming of source code and its derivatives (e.g. executable and installations) and secondary activities that have to do with activities that support the production of that code and its derivatives (e.g. training and maintenance of repositories). In the same way, since different people, organizations and companies participate in the production of FLOSS, both people from the firm and people external to the firm can be involved in these specific activities.

*The primary and secondary activities of the software value chain are t*he following (Pussep et al. 2012):

Primary Activities:

- P1. Research
- P2. Development
- P3. Documentation
- P4. Maintenance
- P5. Production

P6. Marketing
P7. Replacement
P8. Implementation
P9. Education
P10. Technical Support
P11. Operations

S3. Development of Support Technology
S4. Procurement

Secondary Activities:

S1. Infrastructure
S2. Human Resources

Thus, the model proposed in this research focuses first on ordering and classifying these distinctive activities of DI production in three stages. These three stages are 1) Value Creation, 2) Value Proposition, and 3) Value Capture. In addition, this model locates in which of these stages and with what activities each one of the people and groups involved in the production of DI participate, since the cooperative is not exclusively who carries out the activities in this process. These other people and groups and the stages in which they participate are: 1) the Development Community together with the Cooperative in the Value Creation stage, 2) the Cooperative works on the Value Proposition, and 3) the Cooperative, Public , Clients and Users in Value Capture. Table 1 shows in which stage of the process those involved participate. The distinctive activities of the DI value chain will be later described and detailed.

	A. Development Community	B. Cooperative	C. Users
1. Value Creation	**X**	**X**	
2. Value Proposition		**X**	
3. Value Capture		**X**	**X**

Table 1: Presence of each participant in the stages of the DI value chain.

To better understand the three stages of this process, first it is described those who participate in the process and then the specific activities in which they are involved. Those who are involved are : A) Development Community and Collaborators; B) Cooperatives; and C) Users and Clients. Once knowing those involved, it will be easier to understand each specific activity that will be described later and finally the proposed model will order the above and clarify their relationships.

Participants

Development Communities and Collaborators

While the cooperatives that develop DI are at the focus of this research, these cooperatives are part of broader development communities and broader software ecosystems such as those related to programming languages and libraries or content management systems, even web standards. In some cases, cooperatives are one of many among the different people and organizations that contribute to the work that these communities do, contributing a part or a component to a larger framework, tool or system. In other cases, the software project developed by cooperatives is so significant in relation to a certain ecosystem that it has been adopted by a group of developers beyond the cooperative, and for this reason a community has been formed around the project. As indicated by a cooperativist about one of the DI projects that they have developed:

> "We've been very pleased to see the positive reaction this project has received from both the Composer and WordPress communities."

And a year later on the same DI:

> "The response from the WordPress community has been significant. WPackagist is now a core part of WordPress best-practice development, it's frequently referenced in WordPress tutorials, conferences and WordPress books and the project on GitHub has numerous contributions by the WordPress community."

We see in the previous example that this coop's DI has become important in relation to the Composer and Wordpress ecosystems. Other digital technology ecosystems where the DI developed and maintained by cooperatives belong to are: Ruby, React, Redux, Vue, Symphony, Python, Django, Drupal and the Solid web standard. These are both programming languages, as well as libraries, frameworks and content managers among other tools that support, complement or expand the work that cooperatives that make DI do.

For their part, the communities around DI projects in which cooperatives participate are usually made up of freelance programmers, students, workers from other companies, and independent consultants. But as already mentioned, they are not made only of

people but also of organizations that are of different types and sizes. For example, there is a case in which a family business is part of the development community together with the cooperative and the independent developers, in another case there are two cooperatives establishing an inter-cooperation relationship working in a DI project, even there are communities in which a working group of a national institute and non-governmental and non-profit associations collaborate for the benefit of the DI project.

Before continuing, it is important to mention that although cooperatives can be protagonists—along with others—in these development communities, not all of the DI they develop and maintain have been initiated by the cooperative. In some cases we consider the cooperatives as co-developers and maintainers of a project that the cooperative did not began. This will be further elaborated on later.

However, as indicated in the methodological section. One of the criteria for considering a project DI is that its development has to be distributed and therefore have collaborators outside the cooperative. Of course, this happens in different proportions, either because of the size of the project, its usefulness for others, popularity, or even if the cooperative was the one who started the project or not. We found that many of the cooperative DI projects have contributions by outside developers with about 20% of the total code, on average. In a couple of opposite cases, although the least, the contributors who are not members of the cooperative contribute up to 80% of the DI code. In these cases, it is because the cooperative is not the one who began the project, but rather joined its development when there was a community already formed and over time the cooperative has contributed to its maintenance. However we repeat that in most cases found the cooperatives have been initiators or founders of the DI projects.

In terms of geographic distribution, the members of the communities around the DI developed by cooperatives usually go beyond the national borders of the country where the cooperative is located. For example, in one of the projects that have a considerable number of commits from external contributors, they are distributed in countries such as Brazil, Poland and the US, and the cooperative is in India. Some contributors to this project are freelance programmers and others are employees of non-cooperative firms. In almost all repositories there are at least a couple of external developers located in other countries. So due to the number of external commits and also because of the origin of these commits, we can confirm that **the development of DI in which the cooperatives participate is distributed.**

Finally, we can also confirm that although the **cooperatives that develop and maintain DI initiated most of the projects**, it is important to point out that **cooperatives are also organizations that have shown that they can help sustain infrastructure that is already underway**. In return, the cooperative can benefit from offering DI-related products and services.

Cooperatives

The cooperatives that make DI are 12 small and medium enterprises (SMEs) composed of between 4 and 61 people based in: Argentina (3), Canada and India (1), Spain (1), USA (2), France (2) and England (3). In almost all of them the workers are the owners of the company. These cooperatives have teams with a diverse variety of professional profiles. Although more than half are made up mostly of programmers, this is not always the case, since there are some that also have a significant number of people who are dedicated to activities other than programming, such as: business management, project management, consulting, customer relations, accounting, finance and communications, among others. Furthermore, it is very common for worker-owners to carry out more than one type of activity. As an example, it happens that developers, in addition to programming, are dedicated to business development, financial management, human resources or some of the other tasks mentioned above. As one of the cooperative members indicates, many of them dedicate themselves to "whatever is necessary" to manage the cooperative in addition to their position or area of expertise.

To exemplify the range of composition in terms of the professional profiles described above. One of the smaller cooperatives is made up entirely of people specialized in programming. This cooperative maintains the DI with the most dependent packages of all the cooperatives studied, that is, its work is intensive in development and maintenance, which —as its online repository show— thousands of other software projects depend on. On the other hand, we have a bigger cooperative that describes itself as a "digital agency" and is made up mostly of profiles that do not write code and are dedicated to other tasks such as design, management, promotion, etc. However, this cooperative supports two DI projects related to Wordpress and also provides services related to communications such as digital campaigns and it also maintains a physical space for events and coworking.

The previous examples are a sample of the variety of configurations in terms of professional profiles that the cooperatives that make DI currently have. This indicates that co-ops allow for teams with a diversity of skills to be compose of, although they can also be made up entirely of developers and this does not determines whether they develop or maintain DI. In addition, in a cooperative organization where the workers are also owners of the company, whether they are specialists in code or in other activities, they dedicate themselves to more tasks regardless of their specialty, both to sustain the cooperative and to support the development and maintenance DI as we will see later. Thus, in these cooperatives we observe both homogeneous and heterogeneous teams made up either entirely of members specialized in software development who are also dedicated to other tasks, or made up of different specialties who are dedicated to tasks beyond their specialization. Lastly, it is important to mention that although there is a significant presence of professional profiles with scientific and technological higher education, not all cooperative members who develop and maintain DI are scientists or engineers by training, but some of them are dedicated to development and maintenance of software professionally thanks to their extensive work experience in programming, without necessarily having a university degree in engineering.

Public, Users and Clients

Due to the open and public nature of the DI code, there are two types of direct consumers of this kind of infrastructure, the clients to whom the cooperatives provide products and services related to it, and the users of the DI who are not necessarily clients but who use the DI code available on the internet to develop other software projects. These are usually freelance developers, workers at other software companies but also hobbyists and students.

Starting with the clients. Many of the co-ops that develop DI provide different products and services not only related to DI. Thus, in general, regarding all the clients of the cooperatives, we know that they provide products and services to public and private organizations of different sizes, as well as to entities of the social and solidarity economy. Most cooperatives accept a great variety in terms of the types of clients they choose to work with, but there are others that only work for non-profit organizations or for social and solidarity economy initiatives. In this case because they are located in regions where there is sufficient demand from these types of organizations.

Now, specifically, the cooperatives that develop DI-related products and services they offer them to the following types of clients: NGOs, foundations, government institutions, universities, civil society groups, journalists and the media, SMEs, corporate companies, web platforms, other co-ops, unions, etc. As we also see, there's a great diversity of types of clients that benefit from the work the cooperatives do related to DI.

However, DI is not only developed for clients to whom DI is directly provided as a commercial product or service, since it is public software and any other person can use it as long as they follow what is established in each license. This is the case, for example, with one of projects with the most users. We know from its online repository that thousands of developers have used this DI —which is a Ruby library— for: tools to assist in programming, computer security tools, web services, commercial online products and services (e.g. like Google Cloud , Shopify, and Basecamp), web services for government agencies (e.g. the Centers for Disease Control and Prevention), as well as thousands of people who have used it to learn to code. In the same magnitude, we know from its online repositories that 8 Drupal modules that a co-op has developed or to which it contributes to are installed on at least 53,900 websites. In another important case, although on a smaller scale, a tool to manage WordPress plugins and themes highly recommended by its users, has been used at least by small web development companies and several freelance programmers. It is also important to mention that many of these users who are not members of the cooperative also contribute to the development of DI and are part of the development community.

In short, **from businesses and organizations of all sizes to freelancers, enthusiasts and students use the DI developed and maintained by cooperatives; and they benefit from it without necessarily requesting services from the cooperatives** thanks to the fact that they have licensed the code as FLOSS and published it on the internet. For co-ops, it is as important to do business as it is to contribute and serve their communities, in this case the development communities.

Activities of Cooperatives in the DI Value Chain

Overall, the cooperatives that develop DI carry out all the activities, both primary and secondary, of the software value chain. From the research of original software to the continuous operation of online systems, and from the start-up of their own infrastructure up until the acquisition of the necessary resources. This is so, although it

varies between cooperatives, both for the software that they develop that is not DI, and for the 21 DI projects that they develop and/or maintain. However it is important to inquire more into this and show in greater detail the work they do.

Research

Whether it is for DI projects or other software projects, all these cooperatives research and experiment with digital technologies, make prototypes and propose new tools. They develop these prototypes into finished products that they test and make available to the public and other developers such as: modules for popular CMS systems like Drupal and Wordpress, for ERP systems, invoicing software, AI document processing, car rental software, tools to manage databases, etc. Most of these products, although they may have users outside the cooperative, still do not have external developers who are involved and contribute to their code and for this reason they cannot be considered DI to date. The reasons for this may be either because they are new projects, they have not had enough promotion or there is not work time available to dedicate more to them. Even so, the cooperatives have these projects well documented, maintain them and make improvements to them, provide technical support to their users —although sometimes not immediately— and broadly they are active projects, (although there are also some that have already been archived). Together, the 12 cooperatives that make DI have at least 500 repositories with software that they develop and maintain, including some developed inter-cooperatively, that is, between two or more cooperatives. Of all these projects we will focus on 21 that are digital infrastructure and these are DI because thy have dependent packages and external developers who contribute to their code. Although it seems a small amount compared to all the software these cooperatives do, there are 21 DI projects that together have thousands of users that depend on their operation and hundreds of external developers that contribute to their development and maintenance.

As can be noted from the information they publish online and on their repositories, these co-ops are continually developing their own software and therefore one of their main activities is to research new technologies and produce original tools. However, it is interesting to mention that of these 21 DI projects, at least 3 have their origin independent of the cooperative and therefore their initial research was not the work of the cooperative or even the development of its main features. This is not a disadvantage, but the important thing is to point out that although they are not the majority, in some

cases the DI projects have started in another environment and the cooperative has helped maintain it today.[12] This is worth mentioning because DI projects do not necessarily have to began in a co-op (although most projects have), but cooperatives are also organizations that allow already developed DI to be adopted and they help maintain it. This suggests that existing DI projects that do not yet have organizational support can turn to a cooperative or even form their own for this purpose.

Development, Maintenance and Production

Although these cooperatives make software for different applications, either enterprise, desktop, web or mobile, almost all the DI projects they develop (except for one that is for data analysis) are web technology projects. In terms of its duration, the oldest DI started by a cooperative began in 2013 and has its most recent commits every month of the year until June 2022. So it has been active and functional continuously for 9 years. On average, the 21 DI projects have been in existence for 6 years and in almost all of them their last commit was either in 2021 or 2022, so the vast majority are still active.

Although it is difficult to know exactly how many commits are from people that belong to a cooperative, a rough estimate is that they make an average of 80% of the commits of all DI projects, that is, about a fifth of the code is made by external contributors but the great majority is made by the cooperative members themselves. What is clearer is that DI repositories have an average of 67 contributors; from 296 contributors the project that has the most to 5 the ones that have the least. This shows that there are projects that have obtained a large number of external contributors, in some cases above the number of members that the cooperative has.

In addition to developing and implementing new functions, the cooperatives are in charge of maintaining the DI, that is, fixing errors and improving the efficiency of the code through tests and attending to user reports. The vast majority of issues in repositories are closed. Although it is true that not all closed issues are resolved, this indicates that at least the cooperative has paid attention and has taken attended them.

Regarding production, packaging and making the DI available to the public, all but one of these cooperatives have at least one open online repository, with Github and Gitlab.com being the most common, but they also install and self-host their own repositories using the Gitlab and Gitea platforms on their own servers. The cooperative that does not have

12 In some cases probably the need to maintain the DI has been one of the reasons for forming a cooperative.

a repository is because the cooperative members that contribute to the DI code do it with individual user accounts to one of the repositories. As to, in cases where release points are marked in the DI development cycle, co-ops publish release notes that lists the improvements that have been made and the bugs that have been fixed.

As for the dependency of other repositories on this DI, it varies. The DI with the most dependent software has 35,259 repositories that depend on it, followed by another with 12,148; and in the cases that are still shown there are much fewer: 6, 4 and 3 have software dependents. The other repositories do not show how many dependencies they have.[13] However some projects don't have as many dependent repositories they do have external developers that contribute to them, which makes them DI projects.

Finally, it is worth mentioning that all of the licenses of each of the DI projects made and/or maintained by co-ops have a free, open or public domain license; but above all it says a lot that the vast majority are compatible with the General Public License (GPL). The commitment of the cooperatives to the free and open software movements is evident. Although in some cases they are subject to the requirements of the clients and have to work with proprietary systems, all the DI they make and maintain is free and open. As some cooperative members tell:

> *"I am very supportive! We only develop open software and are in turn very reliant on open software. I believe it is crucial for interesting and transformative technology."*
>
> *"LOVE IT. We use it as much as possible. Our work stack is all libre software unless there is so reason to use proprietary software (usually due to interfacing with client systems)."*
>
> *"We publish most of the code we're allowed too as FLOSS (MIT or AGPL). I do think that there are some problems with existing licenses and I'm also interested in the CoopCycle License or the Anticapitalist Public License."*

13 This may be because the repositories are not configured to show their dependencies or because they do not have any.

Documentation

These cooperatives are also very careful to write enough documentation that is detailed, make it available to their collaborators and users and update it, they give it as much importance as the free software movement gives to documentation. This is true for both their non-DI projects and their DI projects. Their documentation is not only in the form of code comments and README files in the repositories, but they also publish dedicated websites using specialized documentation generators.

Technical Support

Technical support is another important activity that cooperatives do and to which they pay a lot of attention. Most of them give a very good follow-up to questions from the users through the issues in their repositories. Even 4 of these DI projects have an online discussion forum to attend their users. Here again there is an important difference between DI projects being very well taken care of compared to other of their software projects showing less frequent support feedback on their repositories.

Implementation

Some of the cooperatives that make DI are not only dedicated to publishing it on the internet and giving users with technical support, they also implement it *on-site* for other companies through consulting services and digitization of business processes. For example, they implement modules related to an Enterprise Resource Planning System (ERP) in other SMEs, cooperatives and entities of the social and solidarity economy:

> *Many times it is also helping them to get organized with an Agile approach, that they begin to do Scrum, that they begin to adopt work methodologies that allow them as a company, as a cooperative, to be able to manage, launch and evolve a digital product.*

When the implementation is not done *on-site*, the cooperatives support the implementation that the user does remotely.

Education

Another activity of the DI value chain that cooperatives pay close attention to is education. They have a large production of online materials for users and other developers to learn how to use and contribute to the DI. This is also a legacy of the free software movement and it shows in the care that cooperatives take when sharing thoughts and concerns related to the DI they develop be it on their blogs, as well as publishing online materials such as tutorials, video-tutorials and guides. In some cases, they give both face-to-face and online workshops related to the DI they develop, either to clients as part of the services they offer or to the interested public. The latter even for free.

Operations

Another aspect that draws a lot of attention in the activities of the DI value chain carried out by co-ops is operations. There are 6 projects where system administration activities are strongly involved. For example, two of these projects maintain live mirror sites, another one a data portal and also a portal that continuously replicates packages from a repository. Another of these DI projects consists of operating various web applications for its clients such as cloud applications for file sharing, video conference rooms, chat and Wiki systems. Finally, in 3 of these projects, in addition to the code being available for download, the cooperatives offer them as software as a service (SaaS) so that users do not have to worry about maintaining the infrastructure they use. In fact, one of these projects has been achieved thanks to the inter-cooperation between two cooperatives. In an example of solidarity between cooperatives, one of them transferred its project to another cooperative so that the last one could maintain it as SaaS and benefit from offering this additional service.

Marketing and Promotion

In terms of marketing and promotion, DI projects are well publicized. Most of them even have their own websites (different from the cooperative's website) and their own Twitter accounts to promote the DI and it's updates and professional logos that identify each project. Also in some cases the work of the co-ops consists of promoting their DI in conferences and events related to software. This is not so clear for the rest of the

software that is not yet DI because many of them —and perhaps this is one reason why they do not have external contributors— lack promotion.

Secondary Activities

These co-ops have proven to be made up of a variety of people with skills other than programming, many have members specializing in management and accounting, two essential skills for any business and for the development ant maintenance of DI. Cooperatives also have members who are specifically dedicated to human resources such as recruiting and training new members or ensuring that members:

> *"are comfortable with their role and project and we look for spaces where everyone can express themselves and contribute their vision of the cooperative."*

Regarding the provision of internal infrastructure, as already mentioned, cooperatives have shown that they can maintain their own infrastructure on which to develop and maintain DI, such as self-hosted repositories and documentation and promotion websites. Related to this, some of the DI projects began as developments of internal tools to help provide the services that these cooperatives offer, such as modules to add functionalities to websites or tools for managing databases that they used frequently in different projects with clients. Realizing that these were tools that could be useful for someone else, they made them publicly available by making them DI, thus demonstrating that cooperatives contribute to the benefit of their communities beyond the commercial relationships they have.

Last but not least, two co-ops reported that they give sponsorship and money contributions to DI projects thanks to the company's profits from people working together. In other words, there are cooperatives that reinvest in DI projects, which allows these projects to be maintained over time.

Creation and Value Proposition

Having shown that cooperatives altogether carry out all of the activities of the DI value chain —although with different intensity between them— this does not mean that the division of labor that is strongly related to value creation (research , development, maintenance and production) or with the value proposition (marketing, implementation, education, support and operations) are carried out exclusively by the cooperative or are

sharply divided between the development community and the cooperative. In the same way that the cooperative is not always the one that initially researches the development of a new project or develops its main functions, there may be times when external contributors collaborate with other tasks beyond development and maintenance thanks that the code is free and open and they can make their own value propositions.

Satisfying the Needs of DI Projects

We previously saw that cooperatives carry out all the activities of the DI value chain. However, research such as *Roads and Bridges: The Unseen Labor Behind Our Digital Infrastructure* by Nadia Eghbal has recognized that DI projects have certain particular needs that must be resolved so that these types of projects can be sustained over time. Among these needs is the lack of planning and workflows, the lack of skills other than programming, and the lack of information and knowledge sharing. Finally, we believe that DI projects also require greater community participation in decision-making and project direction. These needs and how the cooperatives have solved them are explained below.

Planning and Workflows

These cooperatives demonstrate that they can plan the work on the DI, especially in cases where they are the authors or co-initiators of the project. Not only for the implementation of new functions but also establishing future strategies so that the project can be economically sustained over time. Likewise, cooperatives establish the workflows that the collaborators have to follow to contribute to the DI. The vast majority of these projects have contribution guides in their repositories, even for non-programmers, for example for volunteers to do translations. As for having codes of conduct for working in repositories, some projects have them but most don't. In cases where cooperatives are not the authors but have adopted a DI project and are working to maintain it, they provide suggestions to the authors on how the project can be sustained with their collaboration.

Diverse Skills

As already mentioned, the co-ops that make DI can be made up of professional profiles specialized in software development or by members with a diversity of skills beyond programming. However, the teams that are made up of specialized profiles have to attend to other administrative and management tasks to sustain both the cooperative and the DI. As indicated by the member of a cooperative made up exclusively of software developers:

> *"All members participate in all aspects of the business, e.g. marketing, business development, client account management, bookkeeping, financial decision-making, human resources, etc."*

In the same sense, multidisciplinary teams are not forced to not being able to produce or maintain DI. This is so because they have both members specialized in programming as well as people who are enthusiastic about FLOSS and who use their skills as designers, translators and administrators —among others— adding value to the DI production chain.

As we know, the diversity of skills is something that is needed for DI projects to be sustained over time, and cooperatives have shown that they can bring this diversity to work on DI, either with co-ops made up of multidisciplinary teams, by calling in external collaborators with a diversity of skills or in the case of more homogeneous teams, dedicating themselves to other tasks besides coding. In summary, cooperatives that want to develop and maintain DI cannot ignore the lack of skills other than programming, but in one way or another they have to get a multidisciplinary team of people to collaborate, be it integrating different members to the cooperative, dedicating themselves to multiple tasks or attracting external collaborators from different fields.

Information and Knowledge Sharing

Knowledge sharing between members of the development communities is crucial for creating and capturing value in FLOSS development (Morgan 2010). The cooperatives that develop DI know this and for this reason they generate and share information and knowledge with the development community through issues in their repositories and online forums but also with the publications they make on blogs, documentation sites and with their participation at software related events and workshops opened to the

public. This is also a legacy of the free software movement as indicated by one of the cooperativists:

> *"We believe that free and shared knowledge has a potential for growth and adaptation unmatched by any other type of structure. We are against the generation and accumulation of power through the privatization of software."*

Decision Making and Participation

Now, if the DI is intended to be public, it is crucial that whoever produces and maintains it takes into account the development community, the public and its users. So far we can say that cooperatives provide decision-making methods to DI development when it's their own project. What is notable is that in most cases co-ops are open so that those who contribute to the code, whether they are from the cooperative or not, participate in decisions about the technical direction of the project. As one cooperativist comments: “Sometimes our users help us to change the direction”. However, beyond the technical decisions about new functions or improvements, we cannot say that external contributors have the 'last word' in the direction that projects take, although in some cases they are taken into account, when co-ops are authors of the DI they almost always establish the decisive direction of the project.

Results

The model of the DI value chain developed and maintained by cooperatives is presented below. The explanation of this model is followed by recommendations that may be useful for DI projects that wish to adopt the co-op model.

Model

First, this model is based on the double orientation that characterizes the activities carried out by cooperative organizations. On the one hand, the orientation of these activities directed towards the community, and on the other, their orientation towards the co-op participation in market. Second, the model represents the people and groups that participate doing all of the activities of the value chain related to DI production, they are: A. Development community; B. Cooperative; C. Public, Users and Clients. And third,

the model represents the three stages of the process of this value chain in which these people and groups participate. The three stages in which they participate are: 1. Creation of Value; 2. Value Proposal and 3. Value Capture.

This model is illustrated in the *Figure 1* below.

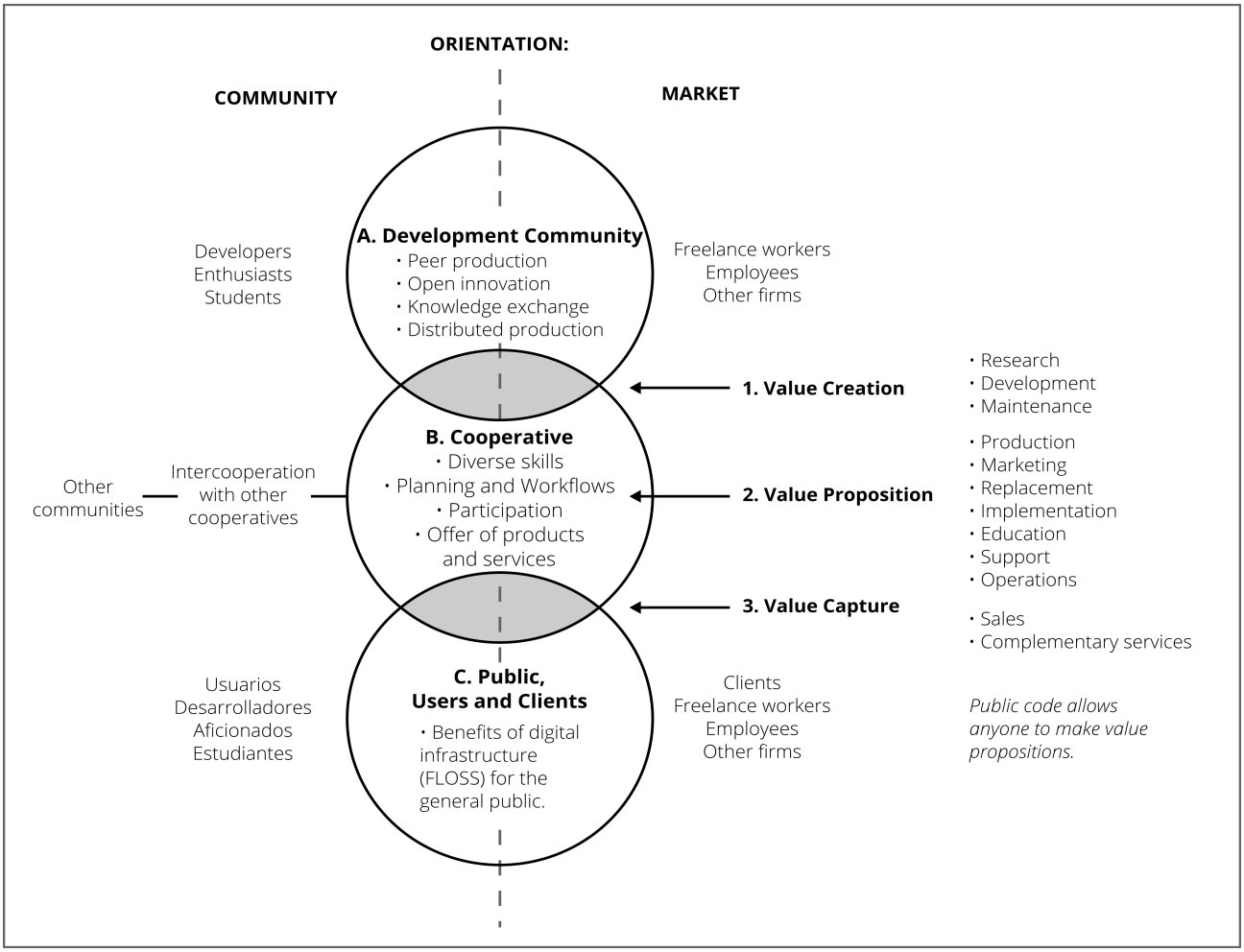

Figure 1: Process and value chain of the cooperative model that develops DI.

A. The development community is made up of individuals and groups from civil society such as hobbyists, students, and non-profit organizations, as well as market participants, such as freelance developers, employees, and companies, all dedicated to creating DI. Indeed the cooperative that has both orientations and by participating in the development and maintenance of DI is also part of this development community.

1. This development community creates the DI by generating value for its current or future users in the following way:

- It does so in a distributed manner, that is, the division of labor is distributed among different people and groups that are in different locations and that do not necessarily belong to the same organization. In other words those who contribute can be members of the cooperative, of another organization or independent.
- The work is done thanks to the exchange of knowledge, like sharing code, documentation, teaching materials and development methods. Suggestions, comments and feedback are also shared.
- Knowledge is shared openly and therefore the results of the work as well. That is, the resulting code is open to the public and is available on the internet with FLOSS licenses.

This distributed and open creation of value because of the exchange of knowledge is known as peer production, since work relationships are established not by a rigid centralized hierarchy but by a more or less horizontal relationship. (Benkler 2017).

The distinctive activities of the value chain that are carried out in this stage are usually the first in the chain such as: research, development, maintenance and in some cases production. The latter if members of the development community who are not part of the cooperative contribute to the packaging or publication of new versions.

B, 2: The co-op, due to its double orientation by participating both for the community and in the market, adds to the value created:

- Diversity of skills that the development community lacks, attracting as members of the cooperative, with the benefits of paid work, people who do not write code but who specialize in administration, accounting, design, promotion, etc. Together they organize their work for the benefit of the DI project.
- Planning, to implement new functions suggested by the users, public or clients, and make administrative forecasting so that the DI is sustained in the long term and thus help cover the costs of work, equipment, hosting, domains, etc.
- Establish clear workflows and guidelines for contributions.
- Offer the result of the work added by the cooperative in the form of complementary products and services, for example by operating a SaaS based on the DI.

The distinctive activities of the value chain that are carried out in this stage can vary to some extent but they generally are those that follow development and maintenance such as marketing, implementation of the DI in a specific organization, education activities such as workshops, dedicated technical support on-site and the maintenance and monitoring of the DI if it's running as SaaS, among others.

Due to its double orientation, the cooperative is especially equipped to make the digital infrastructure available to users and potential clients such as: other developers, cooperative and non-cooperative firms, not-for-profit organizations and other types of organizations that can be or not part of the community that created this infrastructure in the first place. This is made by the cooperative with it's value proposition.

C, 3. Then the cooperative captures the value that is exchanged with the users and/or clients of the infrastructure by selling and adding complementary services, without the cooperative having exclusive rights for this, since together with the community it has produced open public infrastructure, protected with a FLOSS license that allows other members of the development community to also make their value propositions and make it accessible, distribute it and capture value. In the same sense, the DI is made available to the public in an open and free way benefits not only the clients who are given dedicated implementation and support services but it is available online so that anyone can use it and take advantage of the value produced.

Recommendations

Derived from the findings of this research and the input provided by cooperative members, we offer the following suggestions that may be useful to a DI project wishing to form their own cooperative.

Include a Manager: Managing the resources needed to sustain DI is essential for it to last over time. Inviting a person specialized in management to be part of the cooperative will help not only with an effective and efficient management of the co-op, but also with the proper planning and procedures to maintain the DI in the long run, ensuring that work expenses are covered and also equipment and training costs, among others.

Communication and Promotion: Ensuring that the co-op has at least one member who does communication work will be of great help for the promotion of the DI project and help attract people with different skills to the cooperative or as collaborators of the project. They can also support making documentation accessible and communication with the development community constant and helpful.

Decisions and Democratic Direction: The direction aspect of a worker-owned business is central to keeping the co-op democratic and viable in difficult situations. In relation to DI needs, a democratic leadership must contribute to the planning and workflows that DI projects lack. To sustain both the cooperative and the DI, this democratic direction by the members of the cooperative is one of the greatest contributions of cooperatives to the world of economy and work. Whatever democratic mechanisms cooperatives establish for themselves can also be extended to the development and user communities, including them in some of the decisions the cooperative makes about DI. This can be in the form of surveys, open discussion forums, voting, etc.

Support the Infrastructure: The cooperative can contribute to the DI project with the maintenance of development infrastructure, such as providing the necessary resources to have hosting, domain and self-hosted repositories if needed. As well as monitoring the status of these resources and giving them technical support and updates.

Concern for Users: Users of the DI are potential members of the development community. Responding to their requests (even if they are not customers of the cooperative) can motivate them to join the DI development or request implementation and support services from the co-op. The people doing the cooperative's communication work can help with this as well.

Context, Inter-Cooperation and Federations: Forming a cooperative is not an easy task. Especially since there is little information on how to start one and there are also difficult economic environments for Social and Solidarity Economy (SSE) initiatives. In this situation, inter-cooperation between two or more cooperatives can be very useful to support each other, especially at the beginning of a coop. Related do DI, two or more cooperatives can jointly promote DI projects. A network or federation of cooperatives

formed by a group of cooperatives specialized in different technologies will be of great help to share talent, knowledge and resources to carry out projects that a single cooperative could not do by itself, such as implementing and operating a SaaS service. Unfortunately not in all countries there are already networks or federations of software co-ops but fortunately they do exist in countries like Argentina and England and these are a great example to follow and start your own.

13. Contributions and Reach

This research proves: 1) that cooperatives are organizations that can produce and maintain public digital infrastructure, 2) that they carry out all the activities of the value chain of software production and 3) that they do it in collaboration with broader development communities. In addition, the research proposes a model with practical recommendations that can help DI projects that wish to form their own cooperatives. Both the model and the recommendations focus on the diversity of tasks that cooperatives can carry out for the development and maintenance of DI, as well as the importance of collaborating with other developers outside of the co-op.

It is expected that this results contribute to the literature on digital infrastructure by providing important elements for cooperatives to be taken into account as an organization that produces and sustains DI, since they are usually ignored in research about infrastructure and also software production.

The demarcation of the research focused mostly on the provision of digital infrastructure by cooperatives. What would complement these results would be to address in another research its counterpart —the demand— and learn more about the users of the infrastructure provided by these cooperatives and the utility they have of it, be they individuals or organizations. It would also be useful to inquire about the relationships between the seven cooperative principles and the free software principles both of them put into practice in cooperative organizations, since there is an apparent compatibility between the two,. This can be an important influence in the production and maintenance of DI in a democratic way.

14. Declaration of Interest and Funding

None of the people who work and who prepared this research are related by kinship, employment or any other kind with the staff that sponsored the research. There is also no previous history of business relations with the cooperatives studied.

This research was carried out with support from the Ford Foundation, Sloan Foundation, Mozilla, Omidyar Network, and the Open Society Foundations. Thanks to the participating cooperatives for their contributions and reflections.

15. Research Team

Jorge Benet, Fernando Hernández, Imelda Montiel, Carlos Martínez, Omar Valencia.

Consultancy: Jonathan Jesús López Rodríguez.

16. Bibliography

Benkler, Yochai. 2017. «Peer Production, the Commons, and the Future of the Firm». *Strategic Organization* 15(2):264-74. doi: 10.1177/1476127016652606.

CICOPA. 2017. *Cooperativas en la Industria y los Servicios: Informe Mundial 2015 – 2016*.

Dilger, Mathias Georg, Michael Konter, y Kai-Ingo Voigt. 2017. «Introducing a Co-Operative-Specific Business Model: The Poles of Profit and Community and Their Impact on Organizational Models of Energy Co-Operatives». *Journal of Co-Operative Organization and Management* 5(1):28-38. doi: 10/ghfwmg.

Eghbal, Nadia. 2016. *Roads and Bridges: The Unseen Labor Behind Our Digital Infrastructure*. Ford Foundation.

Morgan, Lorraine. 2010. «Value Creation and Capture with Open Source Software: A Theoretical Model for Understanding the Role of Value Networks». 42.

Pussep, Anton, Markus Schief, y Thomas Widjaja. 2012. «The Software Value Chain: Methods for Construction and Their Application». 13.

Šahović, Nikola, y Patricia Pereira da Silva. 2016. «Community Renewable Energy - Research Perspectives -». *Energy Procedia* 106:46-58. doi: 10/gfxfm2.

Spear, Roger. 2000. «The Co-Operative Advantage». *Annals of Public and Cooperative Economics* 71(4):507-23. doi: 10/fwxqg8.

Tardi, Carla. 2022. «What Is a Value Chain?» *Investopedia*. Recuperado 27 de julio de 2022 (https://www.investopedia.com/terms/v/valuechain.asp).