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Motivations, Team Dynamics, Development Practices and How They Impact the Success of Open Source Software: A Study of Projects of Code for America Brigades

Le Chang
University of Denver

Motivations, Team Dynamics, Development Practices and How They Impact the Success of Civic Open Source Software—A Study of Projects of Code for America Brigades

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Le Chang

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Advisor: Dr. Matthew Rutherford

Author: Le Chang
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Advisor: Dr. Matthew Rutherford
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Abstract

Open data movement has nurtured the growth of civic open source software (OSS) in the recent decade. This emerging phenomenon has demonstrated a way that a community can collectively utilize technology to solve its problems.

This study is based on software projects in brigades of Code for America, which is a network of organizations that group volunteers to create digital solutions to community problems. In this study, we analyze the software engineering practices of current civic open source software development, participants' motivations and perceptions of the projects, and provide insights on the antecedents of success of the application development.

A conceptual model is developed to capture potential correlated factors and determinants of the success of civic OSS. We find that leadership, team member's identification as a core team member, and his/her perception of the public benefit level of the project are predictors for his/her satisfaction level. Additionally, we find that compared to team members who are very uninterested in the technologies used in the projects, those who have strong interests in the technologies experience an increase in the odds of stronger willingness to continue in the projects.

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Table of Contents

List of Figures

Chapter Two

Chapter Four

List of Tables

Chapter Three

Chapter Four

Chapter One: Introduction

Technology is developing unprecedentedly fast and penetrating our lives, making them easier and better. However, when it comes to various problems facing every community, technology still fails to play its part. Demand for more effective technical civic services is increasingly rising. But government does not always have sufficient resources to create timely technology solutions. Private sector does not see enough business value in providing technology solutions to municipal services. That is how civic open source software comes to the rescue.

Civic open source software (*civic tech*) is emerging and becoming increasingly influential in all dimensions. With the fuel of the open data initiative and faster application development technologies, there has been a *civic tech* movement in the last ten years, which is a relatively new phenomenon that deserves our study.

We treat civic open source software as a special type of open source software (OSS). Civic open source software helps significantly to enhance awareness of municipal problems, engages citizens, improves governments, and facilitates wiser actions and social change. Many of the projects have significant civic benefits. But more important than providing a technical solution, *civic tech* use prototypes and temporary or sample solutions to bring some civic challenges to the table and enable more people to get involved and together find the best solution and take actions [23]. *Civic tech* might not be the ultimate solution to some municipal problems, but it is definitely an important start to address many problems or at least let people know that solutions are possible. There are many successful civic open source software groups that develop solutions across the world. But they are also facing challenges, such as how to deliver a solution that truly benefits the public, truly improve citizen's life quality, improve government efficiency, and how to ensure ongoing engagement of volunteers to facilitate the development and maintenance of civic OSS.

This study provides facts and analyses of the practices of current civic open source software development, discovering the important factors that impact the vitality and success of the projects. It provides insights for such organizations and volunteers to understand the status quo and improve their software development practices.

Software applications being developed by Code for America (CFA)[1] are analyzed in this study. CFA was founded in 2009. It is a network of over 5000 people creating technology solutions for the problems of over 100 local governments, NGOs, and individuals [56]. The goal of Code for America is to make sure the services provided by the governments are easy for both the governments and the users to use [51]. The reason why CFA is chosen is that it is one of the most representative *civic tech* groups that develop civic open source software and steer the *civic tech* direction. They have shipped successful applications and the network is increasingly influential. As a volunteer in one of the brigades, I am able to observe and study their practices. This study aims at understanding the application development mechanisms and providing insights of how to improve the practices.

[1] https://www.codeforamerica.org

1.1 Research question

The software applications developed by brigades of CFA are what we define as *civic tech*. They are local groups of developers, designers, activists, project managers, etc. They collaborate to create open source software that helps the local communities address pressing challenges. The types of applications they are developing are not confined to just using open data. The source code of all applications is usually on github and everyone is welcome to join and contribute. The development model of these applications is open source software (OSS) development. But it is different than what we consider as "conventional OSS". The "conventional OSS" is developed by volunteers geographically distributed all over the world. Volunteers barely meet. Almost all their communications are through emails, version control systems and bug report systems. There is abundant research revealing the development processes of "conventional OSS" and the developers' motivations, how team coordinate, the quality of the software, and the determinants of success. But for civic open source software created in CFA brigades, members are usually co-located and meet regularly. Their development process is not exactly the same as "conventional OSS". The unique software development process of civic open source software is not systematically studied in the literature. Specifically, we are interested in the development practices of civic open source software, volunteers' motivations, and success determinants of civic applications. Therefore, in this study, the research questions are:

What are the motivations of volunteers?

What are the team dynamics?

What is the development practice?

What factors impact the success?

1.2 Major contributions

The software development practices of civic open source software are still evolving and facing uncertainties. A significant number of studies have been focused on the practices and success of conventional open source software. There is, nonetheless, very little research done on practices of civic open source software.

This study collects raw data from across the United States to get valuable insights into how the volunteers work as a team, what the actual software requirement engineering process, software design, and implementation practices are, and what the relationships among those features are. Additionally, we also discover factors that attribute to the participant's satisfaction level and the project progress rate.

1.3 Thesis outline

The second chapter provides relevant literature review on open source software and *civic tech* development practices, developers' motivations, how teams coordinate the work, what success measures are applicable and what factors impact their success. Next, Chapter 3 introduces the research methods used in this study. Chapter 4 presents the results of the analyses from the data we collected. Chapter 5 discusses the limitations and the scope of this study. Finally, Chapter 6 summarizes the conclusions and suggests future work.

Chapter Two: Literature Review

Open Source Software research has been done in different disciplines. In the Software Engineering and Information Science fields, current OSS research focuses on the following three topics: 1) OSS communities [1], including developers' motivations [2,3], barriers for newcomers [4], and social structure [5], 2) OSS development [1], including development process [6,7,8,42], how the team assign tasks [8], core team size [8], coordination mechanisms [9], and code ownership [8]. 3) OSS Characteristics [1], which include the quality of the software and testing [10,11], defect density [8], determinants of its success [12], success measures [13], and the bug repair interval [8].

The methods used in OOS research are diverse. Since most OSS are implemented remotely, their source code repositories, email communications, bug reports system, version control system, documentations and design artifacts are all online (hosted on SourceForge.net or other websites) and easily accessible. Researchers are able to collect large amounts and varieties of data [6]. According to the review of OSS research by Klaas-Jan Stol et al. [1], case study, quantitative analysis, survey, grounded theory and ethnography are being used in OSS research. Some research studies successful OSS such as Linux, Apache server, and Mozilla Firefox browser [8,17,31,40,46], while others collect a large quantity of OSS projects to analyze the overall characteristics [2,7,12,50].

2.1 Open source software

Open source software refers to the software that is released under an open source license [15,16]. Anyone can modify and redistribute the software. Different than traditional software development approach, this development model, with its source code available to anyone [17], has made tremendous contribution to technology development [18] and impacted everyone's life. Sommerville [15] even claims open source software as "the backbone of the Internet and software engineering". Many open-source products are highly widely used in various fields. The Linux operating system, Java and the Eclipse IDE, MySQL, React.js framework, and Hadoop are just a few successful examples and they all play an important role in today's technology stack.

Because of the success of Apache server, Linux, and Mozilla, which all came out in the 90s, open source software is perceived as a fundamentally new way to develop software and even threatens commercial software. Take Apache web server as an example. According to the Netcraft survey [53], although its market share decreases after 2014, it was the dominant web server between the year 1996 and 2014. As the number of active websites queried by Netcraft grew from 7 million to 180 million in that period, Apache kept hosting 40-70% of all the sites. The Mozilla browser, originating from a commercial product, became open source in 1998. Mozilla Firefox 1.0 was released in 2004 and was a big success with over 100 million downloads in 2004, despite the fact that in 2002, over 90% people use Internet Explorer browser [54].

Eric S. Raymond's [17] famous metaphor—the "cathedral" model, which represents the proprietary software, and the "bazaar" model, which represents the open source software development such as Linux, contrasts the different characteristics of software development models between open-source and proprietary software. In his view, the open source software development model is like a bazaar of different approaches, under which the developers proactively take on tasks and software is frequently released, while the commercial software is “built like cathedrals, carefully crafted by individual wizards working in splendid isolation” and only released when it is completed finished [17]. Tasks of commercial software are assigned in a top-down manner. Eric S. Raymond consciously lead an open source project, fetchmail, with the bazaar style to test the theories about software engineering that are derived from the practices of Linux development. He claims that it is a huge success and the best open source software adopts the “bazaar model”.

Nikolai Bezroukov [19] critiques Raymond’s views on open source software. He points out that the “bazaar” model described by Raymond gives a false illusion of it being a “magic bullet” for almost all problems while it is actually facing some challenges and has its limitations. He believes that OSS community is like scientific community, in which people are motived by status and reputation and these motives may cause burnout in leaders and harm the quality of the product.

2.2 Open data and civic open source software

2.2.1 Open data

The dawn of civic technology is significantly attributed to the open data movement. In 2009, President Barack Obama signed the Open Government Initiative, championing an unprecedented transparency in government. This means that government must make efforts to make their data available to the public and the leaders are seeking greater awareness and usage of this data among the citizens. They sought to involve software developers to make sense of the data, turn it into meaningful information and incorporate it into applications that improve public services and economy [20].

2.2.2 Civic open source software

"Civic open source software" is interchangeably used as "*civic tech*" in this study. Nowadays, technology, cities and civic networks have been more and more interrelated. We have heard the terms "e-gov", "cyberdemocracy", "digital democracy", which all provide some context or suggest important meanings of *civic tech*. There is not an exact definition of *civic tech*. However, there are some features that characterize *civic tech* — "the common good", empowerment of citizens, justice and openness [21]. In short, *civic tech* is technological solutions created by citizens for the public benefit [22].

Some activists believe that technology is a powerful democratizing force [23]. In fact, the founder of the GNU project and also the early advocate of OSS, Richard Stallman, has explicitly stated the political aspect of OSS, in the context of the Free Software Movement since 1983. He believes that everyone should have freedom to control any software, and proprietary software is a tool that is taken advantage of by the people with unfair power [24]. Naturally, some researchers study *civic tech* from a social movement point of view. They perceive *civic tech* or some open source software as a platform to take collective action [25]. There is no doubt that *civic tech* helps increase citizens' participation in public life. In the United States, the civic apps movement started in 2009 and the Obama administration has been supporting it ever since. Civic apps become the bridge between citizens and government, as they are new tools of information and communication [25].

A significant number of civic open source software is related to Internet or mobile applications, which focus on some open datasets coming from local government or NGO [21]. In our study, some applications created in Code for America do not necessarily use open data. But as we reviewed in the literature, "public benefits" have multiple themes, so civic applications comes in all kinds of types and representations. The development practices of all these types of OSS in Code for America brigades are what we study in this research.

2.2.3 Code for America

Code for America (CFA) is under the umbrella of Code for All[2], a network of organizations that use digital technology as new platforms for citizens to engage in the public sphere more impactfully [26]. The *civic tech* movement is not something happening just in United States, it is worldwide. There is Code for Japan, Germany, Tanzania, and a number of other countries. Thousands of brigades comprising local groups of volunteers and civic hackers utilize their technology, design, and project management skills to tackle community problems.

[2] https://codeforall.org

Andrew Schrock makes an interesting metaphor of CFA brigade programs, saying that the way they connect small teams of like-minded civic hackers with local governments is just like the similar model of early firefighters [23]. This metaphor vividly depicts how CFA encourages grassroots engagement, regardless of their skill sets, to participate and solve community problems.

Two successful projects of CFA are GetCalFresh and the Detroit Water Project. GetCalFresh is a mobile-friendly web application delivered by Code for America. It provides a less than 10-minute efficient online SNAP (food stamps) application without in-office visits and lengthy paperwork. It allows easy photograph or other document uploading. As a result, it helps people get CalFresh (SNAP benefits in California) efficiently, dramatically reducing the number of people who are eligible for food benefits but have never applied [27]. This project partners with state governments, county offices and other community groups to help together remove barriers for eligible residents.

The Detroit Water Project, originated from a website by Code for America fellow, Tiffani Ashley Bell, is a web application that find donors to help families who do not have running water. According to [28], the project has raised over $180000 donations in direct payments to the Detroit Water Department on behalf of the residents who had their water service cut off because they cannot afford it. Since 2014, about 1000 families in Detroit and Baltimore have been connected to donors through the project to help pay their water bills.

Both projects strengthen the relationship between governments and the community. As Andrew Schrock [23] points out, even if technology could not solve all the problems, the process of engaging people to collaborate is meaningful. The point of *civic tech* is that it makes us think through problems, not rush to a solution.

2.3 Motivations

Motivation of developers is a central theme in OSS research. Only if we fully understand participants' motivations, can we know how to better manage OSS projects and get the desired results. Motivations that have been discussed in literature include sharing information and interest [2,20], self-realization [2], improving software for personal needs [2,3], solving a problem that can not be solved by commercial software [2], getting help in implementing an idea for software [2], enhancing career opportunities [2,3,20], monetary rewards [2] (some OSS projects pay developers), a sense of joy and accomplishment [3,29], altruism [30], and learning new skills [29,2]. Most of them can be categorized into intrinsic and extrinsic motivations.

G. Hertel et al. [3] collected data from one of the most influential OSS, the Linux kernel project. They conduct a survey based on two theoretical frameworks from social science to get insights of the developers' motivations. The first model is inspired by the motives of people volunteering in community work and acting in social movements. The second model specifies motivations of people working in teams [3]. R. Ghosh et al. find that learning new skills is the top reason for nearly 80% of developers to start with OSS, and half of them want to share knowledge through OSS [2]. Furthermore, they find that sharing knowledge is more important to make developers continue in OSS development [2].

These motivations are not independent. J. Roberts et al. [31] develop a theoretical model explaining the relationships between developers' intrinsic/extrinsic motivations, participations and performances. They also find that developers' motivations are interrelated, and different motivations impact their participation differently.

2.4 Team dynamics

2.4.1 Communication and coordination

Team effectiveness is an important question in various subjects and industries. How teams communicate and coordinate their work and expertise are especially important in software engineering as software engineering is a human-centered activity. Rising et al. [32] claim that scrum teams can cope with frequent changes in software requirements. From research [33] in which team members are equipped with wearable electronic sensors that gather data regarding their social behavior, Pentland finds that the communication pattern is the most important explanatory factor of a team's success. He believes that the communication pattern is as significant as the total effects of all other factors— personality, skills and intelligence [33]. Additionally, in [34], Faraj et al. claim that the expertise coordination among the team members is strongly related to the performance of the team.

When it comes to teams communications specifically in open source software development, a tremendous amount of research reveals how team coordinate and communicate the work of “Conventional OSS.” “Conventional OSS”, as we define, is developed by individuals dispersed worldwide. Some of them work in small teams [3].

Those teams are somewhat “virtual teams.” Developers rarely meet. Developers mostly use electronic media to communicate, lacking spontaneous discussion [35]. However, the success of many OSS with such distributed contributors is impressive. J. Herbsleb et al. [36] analyze how distributed teams overcome the obstacles to informal communication. Y. Yamauchi et al. [35] find that coordination after spontaneous work is effective and the rational team culture helps resolve disagreements among members. Since developers rarely meet, their communication tends to be more rational. Due to geographical dispersion, they have to adopt computer-mediated communication, which has an impersonal nature and is task-focused [35]. The asynchrony of email makes developers communicate more logically with more reflections and little emotional factors. This culture focuses on results, rather than vague ideas and discussions. [35]

2.4.2 Development centrality

Most OSS teams are self-organized [16]. Team structure is like an onion [8], as shown in Figure 1 (adapted from [16]). The most inner circle comprises the core developers. Then the co-developers (the non-core team) make up the second layer. Then outside co-developers are the active users. And the outermost and largest number of actors are passive users.

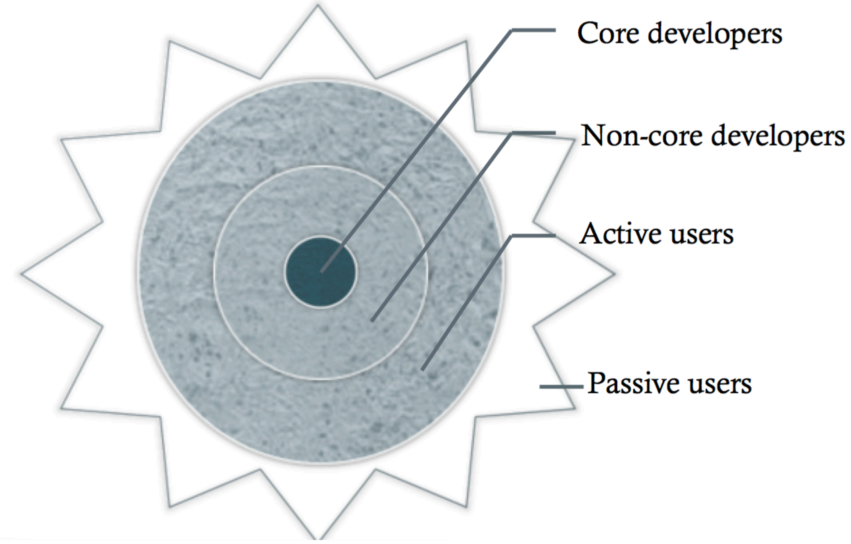


Figure 1: OSS Team Structure (adapted from [16])

It is concluded in some research that in OSS projects, a small number of developers, or even just a single person, completes most of the work [8,9]. There is a much larger number of co-contributors than core members, and an even larger group of users who help report bugs. Contribution is skewed among developers. Some researchers find that more successful teams are associated with more skewed contribution distributions [9].

2.4.3 Task assignment

Different than software development in corporate settings, where leaders assign tasks, developers of OSS tend to choose tasks to work on [8,15,37]. For small projects, which normally do not require explicit coordination mechanisms [19], this is feasible. The leader of a project only needs to perform simple coordination to keep the project rolling.

2.5 Project features

2.5.1 End users

In [19], Bezroukov claims that for any project to continue to evolve, even if it is completed successfully, a majority of users are indispensible. He finds that open source software is more successful if developers are personally interested in it. He points out that the initial prototype of an OSS, usually completed by an individual, is usually developer-oriented. Developers build the software out of their personal needs for better software and out of the pleasure of hacking. For OSS projects like operating systems, programming languages, or editors, where developers are the end users, the feedback is often of high quality. Meanwhile, the developers of these kinds of projects are more likely to respond to the feedback and fix bugs efficiently. For other projects, however, the incentives for feedback providing and bug responding may be much less. And the quality of feedback from developers may not be as high as those of developer-oriented software projects.

2.5.2 Project leaders

OSS projects are normally self-organized. In informal organizations, team members communicate constantly. When most team members are competent and experienced, informal teams can be very successful [15]. In a loose hierarchy, team members are likely to be on a same level and the decisions may be devolved to team members [14]. In a case study of GNOME project, German points out that it has a decentralized decision making mechanism [38]. However, a project leader is still needed to make strategic decisions. As Bezroukov[19] claims, open source may look democratic, but it is actually not. Linux itself is actually the best example. The creator of Linux, Linus Torvalds, has the authorization of rejecting any patches. He controls the Linux kernel. For any project to survive, particularly in its early stages, a determined and committed leader is crucial [19]. As for how leaders are selected, studies show that they are recognized if they are technologically outstanding. These leaders are emergent rather than nominated [35].

2.5.3 Partnerships

A lot of civic open source software involves partnerships. Code for America explicitly suggests that all brigades partner with the local governments and communities [39].

Since civic open source software is for the public good, partnering with city agencies, NGO or advocacy groups is a great way for civic technologist to know what problems truly need to be addressed, how to better envision a solution and how to get access to the best data. Also, partnerships help motivate volunteers of civic open source software. If the partners exist, the applications they develop are more likely to be used and publicized through partners.

However, as Lee et al. [20] suggest, within the city governments, there are many barriers to perfect cooperation with the civic groups, such as the overworked employees, susceptibility to scrutiny, and procurement legislations of the civic agencies. Communications between governments and developers are limited. If city agencies are restrained from involvement in the development phases, chances are they will not adopt or further invest in the software applications [20].

2.5.4 Team size

Eric Raymond [17] claims that one important reason for good quality of OSS is the number of developers and users—"given enough eyeballs, all bugs are shallow". In [8], Mockus et al. claim that the core team size of OSS is not larger than10-15 people. And a much larger group of co-developers repair defects.

Klug et al. [9] find that although team success is not explained by team size alone, team size is a significant predictor of team success. Teams of ten core team members are 300% more likely to succeed than teams of just one core team member.

2.6 Requirement engineering

The requirement engineering practices of Open source software radically contrast the conventional requirement elicitation processes of proprietary software development. In a case study of the Firefox web browser, John Noll [40] believes that in OSS development, developers assert requirements instead of eliciting requirements from target users. Some other research also reports the same phenomenon [41]. Apart from being asserted based on developers' personal experience or knowledge of the user needs, requirements also derive from bug reports, requests for better usability, or competitions of similar software [40,42]. According to the requirement gathering process of the Mozilla project described in [42], decisions of including certain functionalities or changes are based on discussion of bug reports. In the Mozilla project, anyone is welcome to implement a desired change. And interestingly, it is almost certain that it will be accepted to the code base once it is implemented.

Developers of OSS usually start with building software they need themselves [43]. As they are the end users, they have strong domain knowledge of the software requirements, which contributes significantly to the success of the project. But this is only true for advanced OSS that target at developer users. When developing OSS for less technical users, not using traditional requirement elicitation methods might pose risks of poor usability [44]. End users might not understand the technical terminology or user interface presented in the software by developers as a result of lack of user-centered design expertise. In light of these problems, Henderson believes that many traditional requirement elicitation methods could be adopted by OSS as a supplement [45].

In a series of interviews of developers of civic apps, Ermoshina [25] finds a pattern for the way that civic apps are transformed from experience into apps. That is, they normally begin with a personal problem. Then it is converted to an universal solution, which can be implemented through an application. However, it might not always be the case that these apps have a high civic benefit level [20]. Many challenges truly facing the local governments or NGOs are unknown or neglected by developers. Without thorough and effective communications between government agencies and the developers, it is hard for the developers to come up with a solution that really helps complement public services.

After several years of evolving of *civic tech*, developers, as Lee et al. [20] indicate, are more exposed to civic needs and the civic agencies are involved earlier in the software life cycle. Accurate problem descriptions of current challenges are presented to developers. In addition, the data repositories and expected features that the software would need are also provided. Developers are more informed when partnering with governments, NGOs or other advocacy groups that the software targets[20].

2.7 Development process

A number of studies describe the OSS development process based on interviews of core developers, email archives of their source code change history, bug tracking systems or communications history [8,42,46].

Mockus et al. [8] describe the development process of the Apache server based on a description drafted and fact-checked by core team members of the Apache server project. They reveal a special development and decision-making process, including the email lists and a quorum voting system. The Apache project has an Apache Group (AG), an organization of core developers, who are identified and nominated among the community. As the authors of [8] describe, each developer goes through the following processes during the software development — identifying a problem, deciding who will implement code to solve the problem, finding a solution, writing the code, requesting the AG to review changes, and finally committing to the repository.

2.8 Success measures

To discover what makes an OSS project successful, we need to first define the meaning of success in civic open source software. There is some research analyzing the success measures for OSS and civic technology [47,12,9].

Success measurement for OSS is a multidimensional construct. It is used according to the specific cases. Researchers have been focusing on the system process, activity level and the impact on individuals [47]. Lee et al. [13] develop an OSS success model drawing on the features of OSS and a classic information system success model. They summarize five measures for OSS success—“Software quality”, “Community service quality”, “OSS use”, “User satisfaction”, and “Individual net benefits” [13]. In [12], researchers find that some success measures are inter-related.

Crowston et al. [47] examine the validity of applying the success measures used in information systems research in the free/libre open source software (FLOSS) context. After reviewing the success measures in literature and analyzing the different process models of general information system and FLOSS, they provide a series of measures of FLOSS effectiveness and suggestions on how to operationalize them. These measures are: Project output, which has indicators such as progress of a project and developer satisfaction; Process, which is indicated by the number of developers, activity level, release cycle, and the time interval to implement features; Outcome for project members, which has indicators including career opportunities and reputation gaining.

Gasser and Scacchi [6] provide a summary of characteristics of empirical OSS studies. They identify the different objects of the studies, their corresponding success measures and the drivers of the corresponding measures. The most relevant research object they have identified is the software process, measured by project efficiency and adaptability to changes.

2.9 Determinants of success

2.9.1 End user

If developers or other team members are end users of the software themselves, the requirements engineering will be easier and more efficient as they know what they need and can develop quickly with high quality [16]. The project itself, if is something used by developers, suggests potential high quality of the OSS.

2.9.2 "Onion" team structure

Mockus et al. [8] have made a hypothesis that even for a project that has a strong core team, if it cannot attract a large quantity of co-developers, the project will fail due to the lack of people helping with bug fixing or implementations of small features. The success of Apache server also shows that a magnitudinal larger number of users who help find and report bugs are correlated with the quality of the software [8]. Therefore, the team structure could be a factor that impacts the success of the project.

2.9.3 Partnership, life cycle phase, and activity level

Stewart and Ammeter find that sponsored projects are more popular (popularity operationalized as the number of subscribers to the projects and the traffic level of the project’s website) than non-sponsored projects, but project vitality is not affected by sponsorship [7]. Wynn [48] finds that the level of fit between the project life cycle phase and the project characteristics is another factor that affects the project success. Subramaniam et al. [12] find that the current project activity levels influence the subsequent activity levels. Stewart and Ammeter [7] find that projects in the alpha stage show greater increases in popularity than those in mature stage.

Chapter Three: Research Method

We conduct an anonymous online survey to collect the data. Survey items include demographics, features of civic open source software projects, team dynamics, software engineering practices and volunteers' perceptions of the projects. The survey is distributed through anonymous links to all brigade members across the United States. Data is collected in Jan 18th – Mar 27th 2018.

3.1 Survey distribution and respondents

The survey was sent out to all 63 brigades of CFA. We obtained the comprehensive list of brigades of Code for America from the Code for America website. And we got the contact information of brigade leaders, brigades' Slack channels, and their social media account names from a shared brigade contact directory and with the help of CFA full-time staffs. The survey was posted in TWICT (this week in *civic tech*) newsletter in February, which is maintained by CFA and subscribed by many brigade members. The anonymous survey link was first sent via email to all brigades leaders along with the request for them of helping send out the survey to their brigades. Then, to publicize the survey as much as possible, it was posted in CFA and brigades' Slack channels (the main team communication tools used by most brigades), brigades' Facebook pages, twitter accounts and meetup pages. Anyone who has ever participated in the software application development projects, no matter they were active or not at the time of seeing the survey, is welcome to fill it out.

Within an approximately two-month time frame, we got 143 responses. It is worth noting that a non-response bias exists in our data, which limits the generalizability of the results. The locations, roles of volunteers in the brigades, and brigades members' limited access to the survey are the major reasons for the non-response bias. We will discuss these limitations in detail in Chapter 5. From all the responses we have got, we removed responses for which the completeness is less than 50%. This left 115 observations. Respondents of the survey include all actors in the civic open source software ecosystem—brigade captains/co-captains, developers, designers, project managers, and government or community partners. They are all integral parts of civic OSS and provide important viewpoints for us to find the insights regarding our research questions.

3.2 Survey questionnaire

Questions in the survey are mostly multiple choices with options for free form answers. The survey takes 8-10 minutes to complete.

Since members of brigades might have been involved in multiple projects or have engaged in more than one brigade, respondents are asked to identify a project (a civic open source software application) they have participated in and base their answers on that project. Explicitly asking them to identify a certain brigade and a certain project helps avoid repeated or noisy data.

The survey consists of five parts, which include motivations of volunteers, team dynamics, software development practices, and their perceptions of the projects. In terms of the inferential statistics analysis, the survey questions contain response variables (willingness to continue his/her participation in the project, satisfaction level, and project progress rate), and explanatory variables (demographics, team size, team partners, and a number of other items) that could possibly explain the response variables.

The first part asks respondents about demographics, motivations and context-related information:

- The brigade that they are volunteering in or have volunteered in
- Gender
- Current activeness status
- Length of their engagement
- Frequency of his/her participation in the project
- Roles in the project
- Primary role in the project
- Whether he/she is a core team member
- Interest in the technology
- Motivations

The second part is about the features of projects:

- Whether he/she is the target end user of the software application
- The initial status when he/she first joined the project
- Whether the project is well led

- Whether there is a government or community partner involved
- Whether the MVP (minimum viable product) is completed

The third part consists of questions about team dynamics. We ask:

- Size of core team and non-core team
- Number of male and female team members
- Communication frequency within team
- Primary team communication means
- Team communication effectiveness

The fourth part of the survey contains questions about the software engineering practices:

- Team-partner communication effectiveness
- Requirement elicitation means
- Requirement elicitation frequency
- Requirement documentation
- How, when and how often partner is involved
- Systematic software architecture or component design
- Documented user interface
- Task assignment
- Development centrality (how contribution is distributed)
- Time interval for substantial project progress

The last part of the survey consists of questions regarding volunteers' perceptions of the project. We ask:

- Level of civic benefit
- Whether the software will be completed and used
- Self-efficacy
- Willingness to continue his/her participation (if he/she is active at the time of taking this survey) or return to participate in the project (if he/she is not active at the time of taking this survey)
- Reasons for leaving (we ask those who were not active in the brigades at the time of taking the survey)
- Overall satisfaction level of the project.

Lastly, we ask the respondents an open question about their comments regarding participating in the projects or the survey. The full survey questionnaire is listed in the Appendix.

3.3 Data analysis method

After obtaining the raw data, data cleaning is conducted to prepare for analysis. We check the accuracy of the data, change data format, and assign each question a "variable" name to represent the item. All data cleaning, analyses and visualizations are conducted using the R programming language and software environment (version 3.4.3).

In the analysis, descriptive statistics are used to provide a view of the data features. Along with it, we use graphics to help with the visualization of the descriptive data. We also use inferential statistics method to infer from the sample data the associations between the project features, team dynamics and the success measures, and discover the antecedents of the success of the project.

For inferential statistics analysis, we first use multiple imputation to handle the missing values. Multiple imputation is an increasingly adopted method used in research to help fully utilize the recorded data and avoid introducing a substantial amount of bias. Among our 115 observations, 71.3% are complete. As for the percentage of missingness in the variables (survey items) that are used in our inferential analyses, the results are shown in Table 1.

Variable	Missingness
Partner.presence	0.9%
Participation.frequency	0.9%
Team.communication.frequency	6.1%
Female.number	5.2%
Core.team.size	6.1%
Team.communication.means	8.7%
Team.communication.effectiveness	8.7%
Project.progress.efficiency	14.8%
Interest.of.tech	1.7%
Will.be.used	0.9%
Self.efficacy	7.8%
Willingness.to.continue	0.9%
Satisfaction	3.5%

Table 1: Missingness of Variables

The MICE package for R is used in our study. In this package, to impute categorical variables with more than 2 levels, “polyreg” (Bayesian polytomous regression) is used. And to impute ordered categorical variables with more than 2 levels, “polr” (Ordinal logistic regression) is used. We specify an imputation model for each variable and impute data on a variable-by-variable basis. In total, we create 10 predictions for each missing value.

After we get the 10 fully imputed data sets, Spearman's rank correlation test, simple linear regression, and Fisher's exact test are performed to test our hypothesis. In our analysis process, if both variables are ordinal variables, we use Spearman's rank correlation coefficients and simple linear regression on the ranks of both variables to test the correlations. If one of the variables is nominal but the other variable is ordinal, we treat the ordinal variable as nominal variable and use Fisher's Exact test to test the independence of the two values. If both variables are nominal, we use Fisher's Exact test.

To identify predictors of success of civic OSS, we use Ordinal logistic regression. Ordinal logistic regression is an extension of binary logistic regression. It is used when the dependent variable is an ordered categorical variable. This model fits our data and research questions in that we want to discover what factors affect the success measures, which are ordered categories in our case. After we conduct the analysis on 10 imputed data sets separately, the results are combined using Rubin's rule.

Chapter Four: Findings and Results

As we specified in Chapter 3, the inferences are limited by the non-response bias and therefore should be used with caution. The descriptive results of the analysis are presented in section 4.1- 4.4, where we report the results of the development practices such as how teams communicate with partners, what the requirement elicitation process is, and whether the project has systematic design and development centrality of the team members. The results of inferential analysis are presented in section 4.5. In this section, a conceptual model capturing groups of variables is presented. Our hypotheses are tested and the predictors of the success measures are explored. (As there are some items that allow more than one answers, we do not impute these items. Therefore, the results in section 4.1-4.4 are based on the 115 observations without imputation. The results in section 4.5 are combined results based on imputed data sets.)

4.1 Demographics and context-related information

4.1.1 Brigade locations

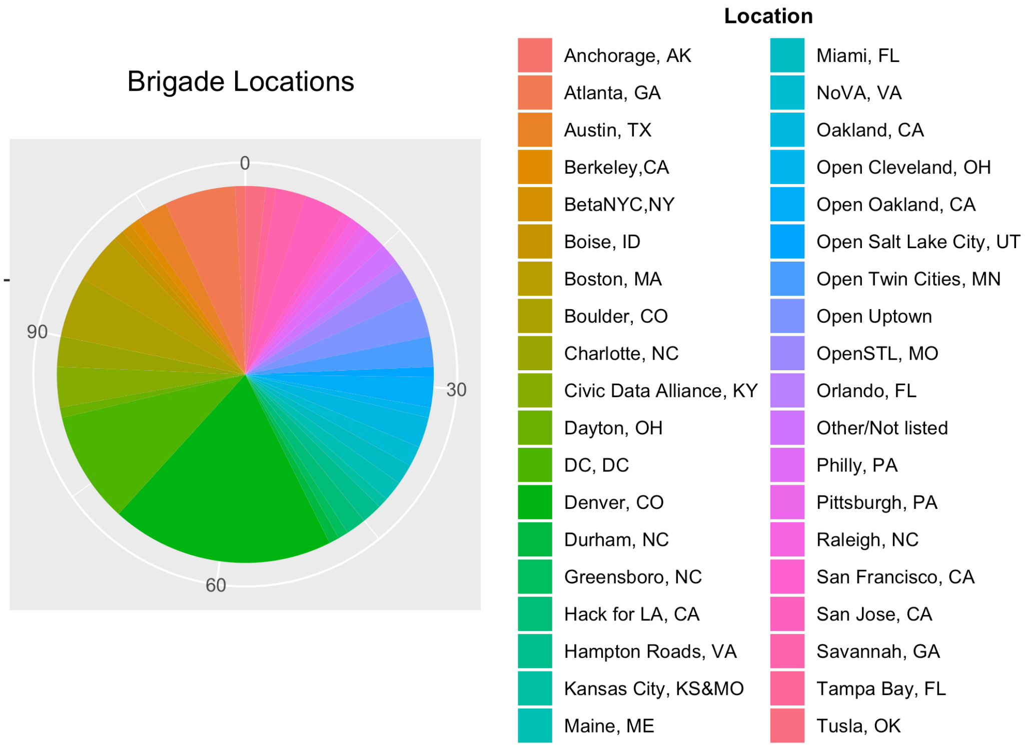


Figure 2: Brigades

The geographic locations that the respondents represent are quite dispersed, while certain brigades provide more responses. Code for Denver, DC, Atlanta, and Boulder have 22,11,7, and 6 responses respectively. This is partly due to the fact that we are based in the Denver area. And the size of the brigades, the extent that the leaders promote the survey and the activity level of brigades influence the survey response rate across different brigades.

4.1.2 Gender and roles

Among the 115 observations, 63% are males, and 32% are females. 103 respondents are currently active in the projects, while 12 are not.

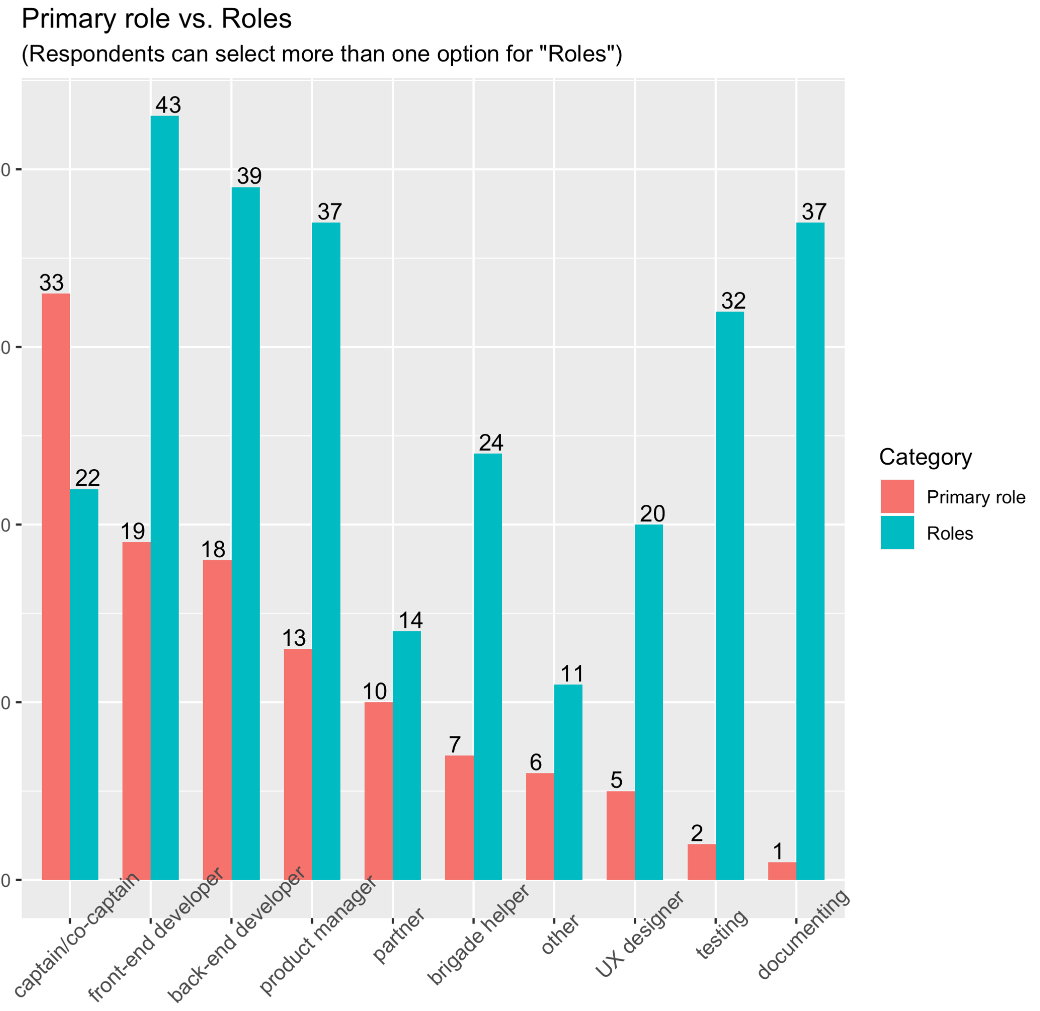


Figure 3: Primary Role and All Roles

Figure 3 shows the distribution of respondents' primary role and all roles they take. 33 respondents are brigade captains/co-captains. There are 19 front-end developers and

18 back-end developers respectively. 13 respondents are product managers and 10 are government/community partners. A few respondents are UX designer or testers.

In CFA brigade projects, members may share multiple roles. As shown in Figure 3, compared to the counts of each “Primary role”, the counts of “Roles” at least double (except for “brigade captain/co-captain”), which means that most of them take on multiple roles in the projects. Testing and documenting are the two roles that significantly soar when respondents choose all roles they take. This indicates that testing and documenting are mostly shared by team members.

As for the reason why the number of “brigade captain/co-captain” for “Roles” is less than the number for “Primary Role”, we find that some respondents do not include “brigade captain/co-captain” in their answers to “All Roles” even though they identify “brigade captain/co-captain” as their primary role. It might be due to the gap of the understanding of the questions between respondents and us as survey designers. This accountability issue is also discussed in Chapter 5.

4.1.3 Length of involvement and participation frequency

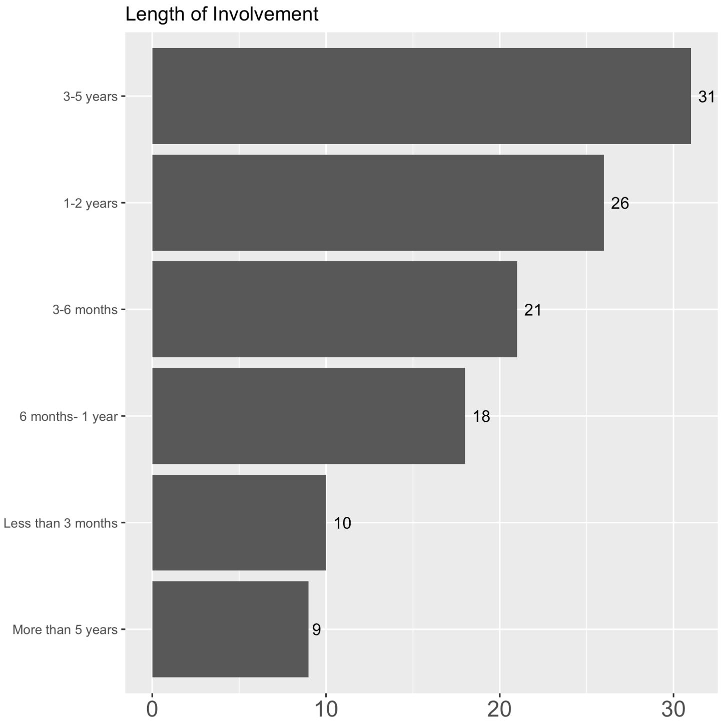


Figure 4: Length of Involvement

Lengths of engagement vary from less than three months to more than five years, as is shown in Figure 4. It is worth noting that the highest percentage of length is 3-5 years, which might not represent the actual distribution of such length of involvement among brigade members. This might be due to the fact that we sent survey directly to the brigade captains and posted it in their slack channels. Brigade leaders usually are involved for a relatively long time, and might be more interested in taking the survey.

As for the frequency of members' participation, 37.9% come to the meetup once a month and 40% once a week, which together account for 77.9% of all respondents. There are 6% respondents who come to the meetup more than twice a week. We ask those respondents how many hours per week they spend on the projects. 3 of them spend 6-15 hours, 3 of them spend 16-25 hours and 1 respondent, who is a brigade captain/co-captain, spends even more than 25 hours every week.

4.1.4 Core team member

Among the respondents, 70.4% consider themselves as core team members, while 14.8% do not think so. 14.8% choose “maybe”, suggesting that they are not sure how significant their work is to the whole project.

4.1.5 Interest in the technology

From our observations and what the literature has revealed, learning new skills and sharing skills are important motives for developers to participate in the “conventional OSS” and the civic OSS development. Therefore, we want to know if developers and other team members are interested in the technology being used in the projects and how this factor may affect the project.

We ask respondents their interest level using a 5-level Likert scale (ranges from “very uninterested” to “very interested”). Among all the respondents, 37.4% are very interested in the programming languages, frameworks or other technologies used by the project, while 23.5% are interested, 18.3% are neutral, 10.4% are not very interested, and 6.1% are very uninterested. Specifically, we are interested in the results from just front-end and back-end developers. Among all the developers, 83% of them are very interested or interested in the technology being used. Only 5.1% are not interested or very uninterested.

4.1.6 Motivations

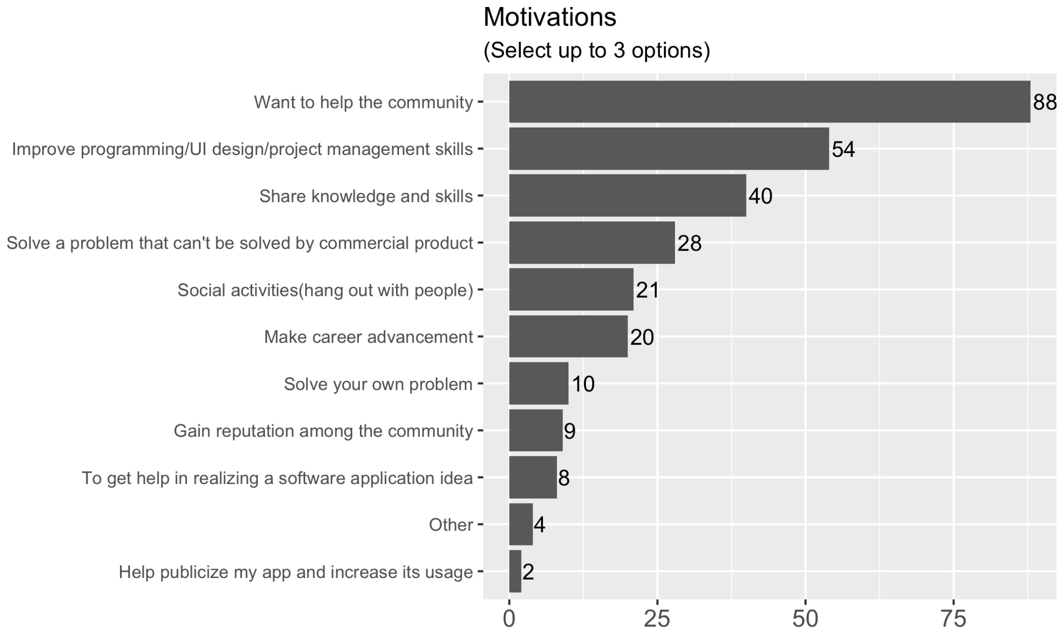


Figure 5: Motivations

From the results, we can see that 88 out of 105(83.8%) respondents want to help their local communities. And there are 28(26.7%) people who want to solve a problem that cannot be solved by commercial product. This is a reflection of the motives found in the voluntary actions in community work [3]. On the other hand, 54(51.4%) people want to improve technical or management skills. And 40 (38.1%) respondents want to share their knowledge and skills through volunteering in the projects. These two motives show their strong motivations to work in teams. Some respondents also report that they are motivated because they treat it as a social activity or want to make career advancements.

We also ask those who are not active in the projects at the time of taking the survey why they have left the projects. 12 respondents are inactive and provide the reasons. Results vary a lot. Limited time, skills mismatch/low self-efficacy, and poor project vitality are the top reasons that discourage volunteers.

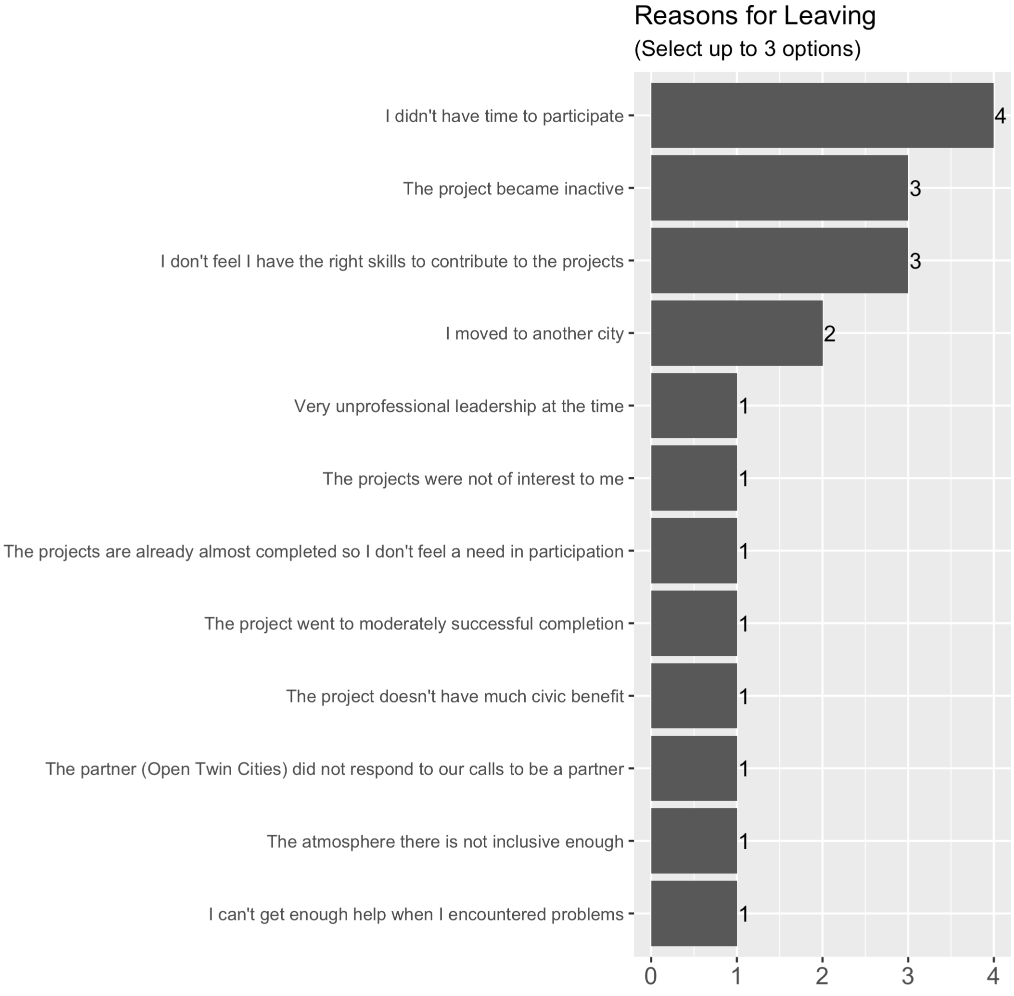


Figure 6: Reasons for Leaving

These responses shown in Figure 6 indicate that project features, such as leadership, support from partner, vitality, and volunteers' personal factors, such as self-efficacy, are reasons that volunteers leave, and we can logically infer that, they are also important candidates to be considered as the factors that affect project success.

4.2 Project features

4.2.1 End user

Researchers have revealed that the developers of "conventional OSS" are normally end users of the software product, which is an important reason for their success even though they do not practice rigorous requirement engineering process. Therefore, we are interested in knowing whether the developers and other team members are the end users of the civic OSS projects. We want to compare these projects with "conventional OSS" and see if this could be a factor affecting the success of civic OSS.

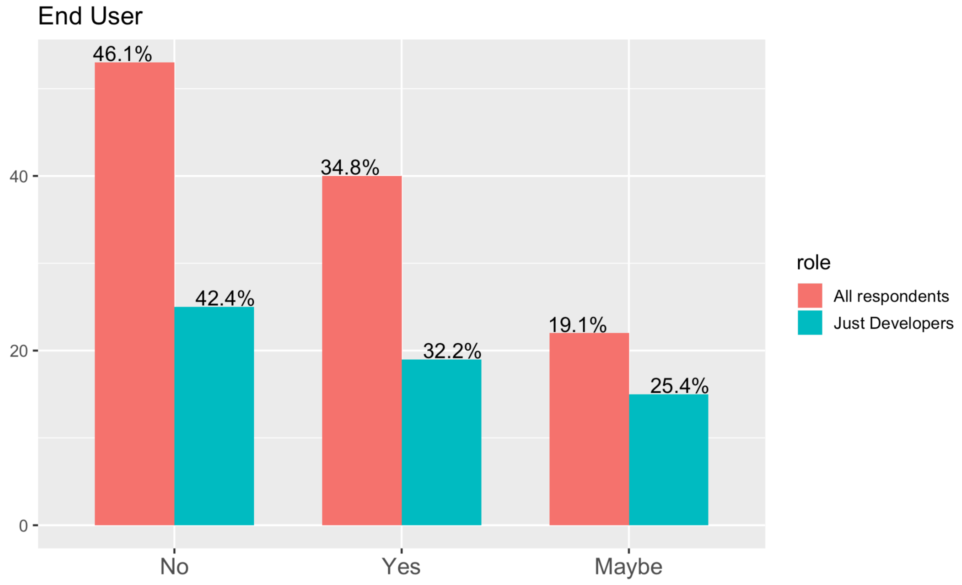


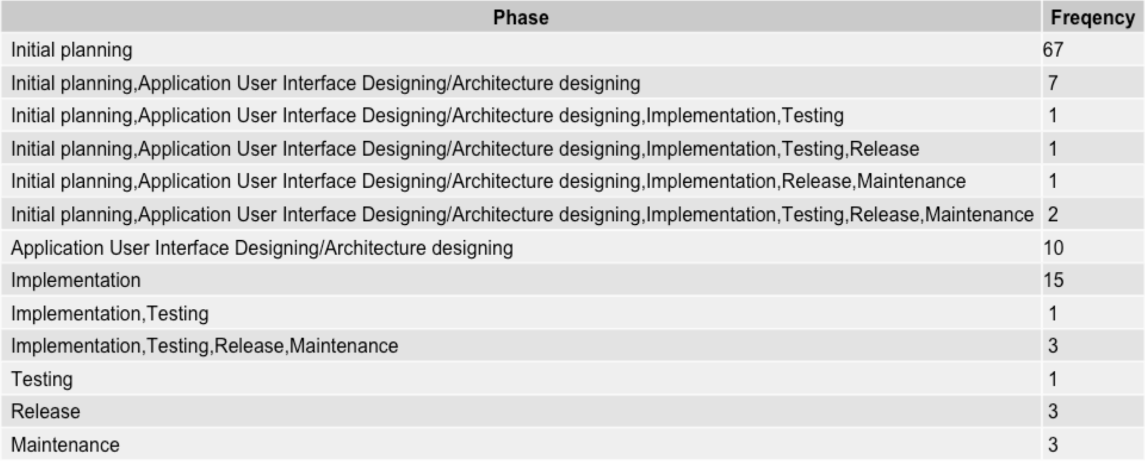
Figure 7: End User

Figure 7 shows that among all respondents, 46% are not the end users, while 35% are the end users. 19% say that they may be the end users. In particular, we want to know the results among developers. Our results show that only 32% of the developers are target users. This suggests that the majority of the civic OSS projects are not specifically targeting at software developers or technical users.

Developers may be the end users of the software because it helps their personal lives or because it is a software development tool (i.e. an operating system, a programming language, or a web development framework) that they need in their programming work. Good "conventional OSS" tends to be started by developers who "scratch their personal itches" [55]. Our results show that few developers are the end users of the *civic tech* that they participate in.

4.2.2 Project phase

CFA brigade projects adopt Agile software development methodology, where software development phases are iterative and interwoven. We ask respondents to choose the project phases (they can choose multiple answers in that a project can be under multiple phases at the same time) when they initially joined it. As shown in Table 2, 79 out of the 115 (68.7%) respondents joined the project when it was under the initial planning phase, or initial planning together with software design, implementation and other phases. This is consistent with the literature and our observation that people are more likely to be attracted to a project that is in its early phase. In the alpha phase of a project, participants can get a greater sense of achievement and learn new skills fast since a new project requires a lot of break-through work.



Phase	Freqency
Initial planning	67
Initial planning,Application User Interface Designing/Architecture designing	7
Initial planning,Application User Interface Designing/Architecture designing,Implementation,Testing	1
Initial planning,Application User Interface Designing/Architecture designing,Implementation,Testing,Release	1
Initial planning,Application User Interface Designing/Architecture designing,Implementation,Release,Maintenance	1
Initial planning,Application User Interface Designing/Architecture designing,Implementation,Testing,Release,Maintenance	2
Application User Interface Designing/Architecture designing	10
Implementation	15
Implementation,Testing	1
Implementation,Testing,Release,Maintenance	3
Testing	1
Release	3
Maintenance	3

Table 2: Project Phase When Initially Joining It

4.2.3 Project leadership

"Conventional OSS" is known to be mostly self-organized. But researchers have also suggested that successful OSS, like Linux, actually has leaders who help control the software. In our data, 67.8% respondents think that the projects are well led by the leader(s). 8.7% think that the projects are not well led. And 23.5% respondents point out that their projects do not have a clear leader. This result suggests that overall, there are leaders in the projects, and a majority of the projects are well led.

4.2.4 Project partner

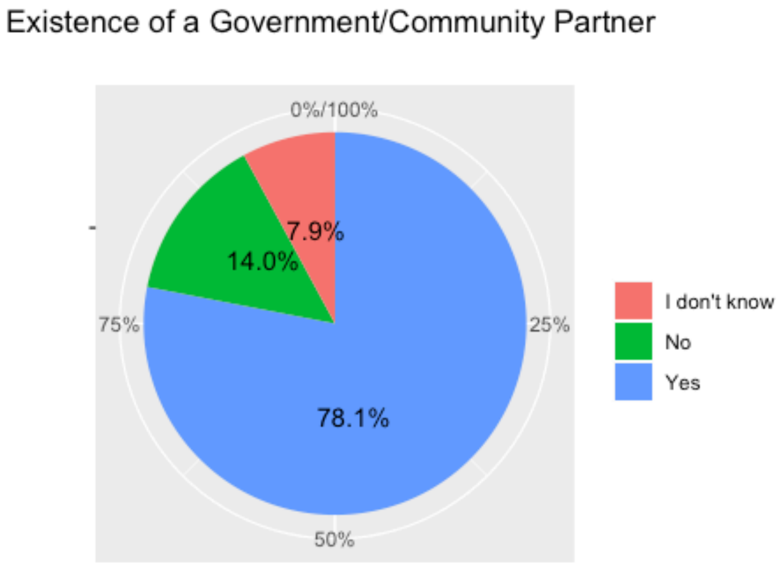


Figure 8: Existence of a Government/Community Partner

We observe that 78.1% respondents' projects have a government/community partner. This is consistent with what CFA advocates—work with local government and community organizations, from whom they will get access to more data and know the major challenges facing the community. From our observations of the projects of Code for America brigades, participants work with city servants and citizens affected by the problems to gather requirements and form a solution. The existence of a government/community partner not only provides requirements, but can also help team members form a feel that their project will be used (Hypothesis 3). We will show the result of the hypotheses tests in section 4.5.2.

4.2.5 Project MVP

From our observation, most CFA projects are ongoing. Minimum viable product (MVP) is an important milestone for CFA projects to mark their achievements. Our data shows that 57.3% of the respondents choose to report on a project that has already reached its MVP milestone. 28.1% report that the MVP of the project that they choose will soon be completed. Only 14.6% of the respondents say that the MVP of the project of their choice is not completed or they do not know.

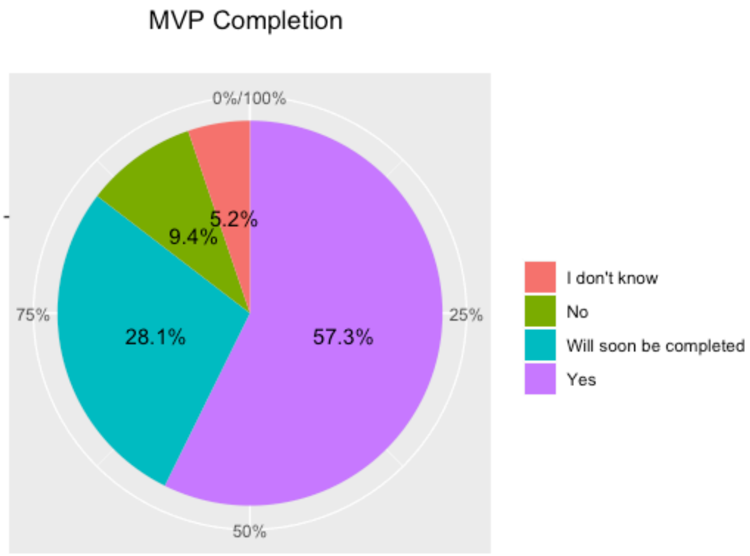


Figure 9: MVP Completion

4.3 Team dynamics

4.3.1 Core and non-core team size

As reviewd in the literature, successful OSS tend to have a core team of less than or equal to 10-15 developers, who will create about 80% of the new functionalities. In our civic open source software project, our core team is not limited to developers; anyone who contributes to the project substantially, such as the UX designers and project managers, is also considered as core team members.

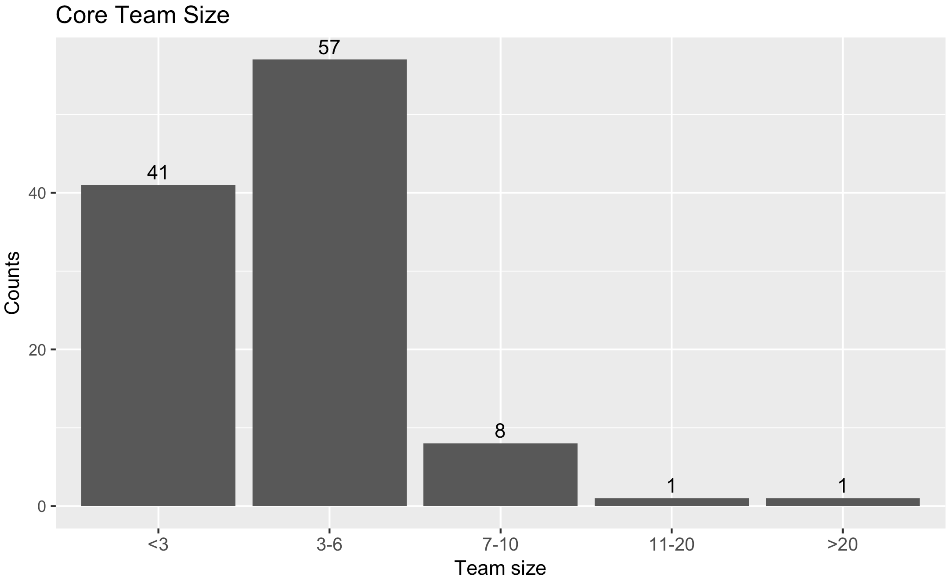


Figure 10: Core Team Size

As shown in Figure 10, in our data, 41 repondents report that their core team size is less than 3 people and 57 repondents report a core team size of 3-6 people. Together, 98 (90.7%) respondents indicate that the core team size of CFA projects is 1-6 people, which is smaller than the core team size of “convential OSS”, even though *civic tech* teams include roles other than developers. This difference of team size can be explained by the differences between *civic tech* projects and the “convential OSS”. *Civic tech* focuses on local community, where the number of available participants are limited by the size of the community and the number of local civic technologiests. *Civic tech* projects tend to focus on involving local people to volunteer, not attempting to get more volunteers from other areas online, although the repository is public. And those outside the certain community might not be interested enough to join the projects. Additionally, with the help of new web and mobile development frameworks, most of the applications developed in CFA brigades are light weight, not requiring much advanced technical skills. Therefore, the team size can still be considered fit and effective although they are relatively small.

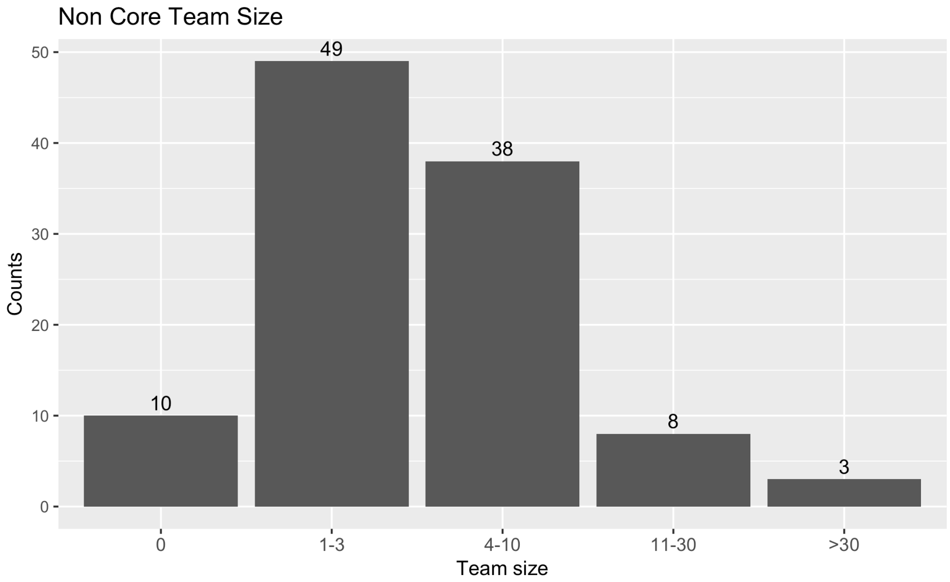


Figure 11: Non-core Team Size

The non-core teams are those who help with the defect detection, reuqirements analysis and other software related work. In our results, 10 respondents report a non-core team of 0 person, and 49 respondents report a non-core team of 1-3 people. 38 respondents report a non-core team of 4-10 people, 8 respondents report a non-core team of 11-30 people, while 3 respondents report a non-core team of size over 30. As we can see from the comparison of Figure 10 and Figure 11, there are slightly more non-core teams of size over 10 people than core-teams of size over 10, but the pattern is not obvious. In order to check the comparison of core-team size and non-core team size for each project respectively, we create a cross tabulation of the data. Results are shown in the Table 3.

	Non-core team size					
Core team size	0	1-3	4-10	11-30	>30	Total
<3	5	21	13	0	1	40
3-6	4	26	22	5	0	57
7-10	0	2	3	2	1	8
11-20	0	0	0	1	0	1
>20	0	0	0	0	1	1

Table 3: Core vs. Non-core Team Size

From Table 3, we can see that 5 out of 40 (12.5%) respondents report that their core team size is less than 3 and they do not have any non-core team member. 21 out of 40 (52.5%) respondents report that their core team size is less than 3 and their non-core team size is 1-3 people. For projects that have a core team of size 3-6, 4 out of 57 (7%) respondents report that they do not have any non-core team member, while 26 out of 57 (45.6%) respondents report a non-core team of size of 1-3 people. These results show that about a half of the projects do not have a larger number of non-core team members.

The literature suggests that successful OSS developments tend to have an “onion” team structure. That is, they have a much larger group of non-core developers to fix bugs and even a larger group of participants who report problems. Our survey results reveal that for civic OSS projects in CFA, most projects do not have the same “onion” team structure. In CFA projects, the majority of projects have 1-6 core team members. About half of all projects have approximately a non-core team no larger than the core team, and half of them have a slightly larger number of additional contributors than the core-team. Few projects have a significantly larger group of non-core contributors like successful “conventional OSS”. One of the possible reasons is that most CFA projects are under development and are not released yet. There are no ways for these projects to get a very large number of users to report bugs.

4.3.2 Team gender composition

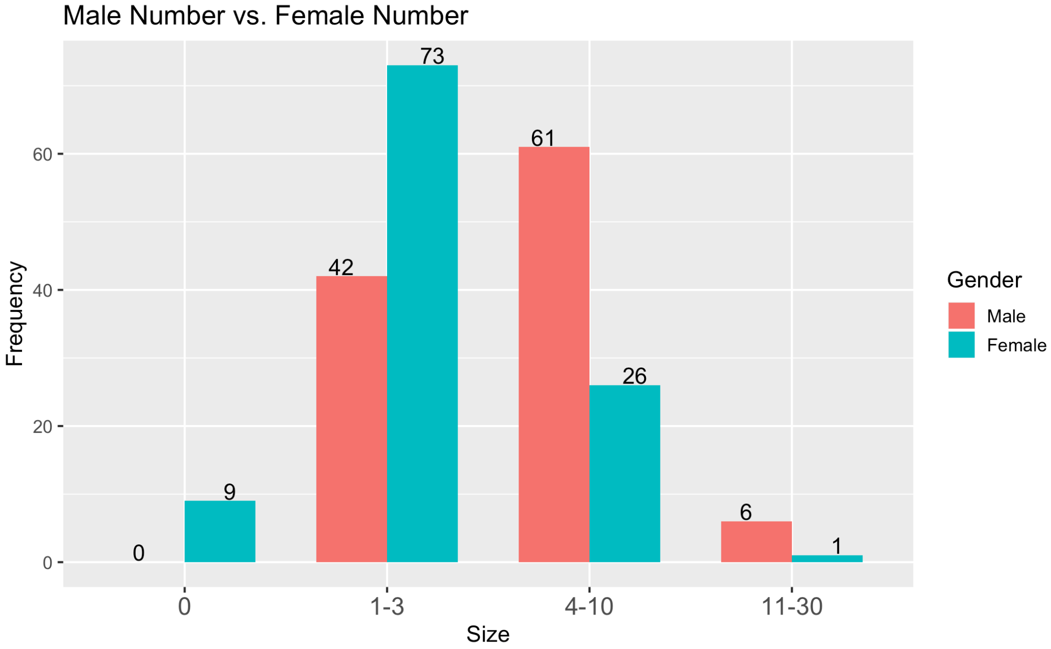


Figure 12: Female Number vs. Male Number

We ask respondents how many males and females that their teams have respectively. And we give them some range choices: 0, 1-3, 4-10, and 11-30. Referring to Figure 12, which shows the distributions of the frequency of male number and female number in each size group, we can see a pattern that in CFA brigade projects teams are generally composed of more males than females. The mode of the distribution of female number is 1-3 people, while the mode of the distribution of male number is 4-10 people. 9 respondents report that no female member is on their teams while no respondent report 0 male member on their team. 73 people report 1-3 female members on their team, while 42 people report 1-3 male members on their team. 26 people report 4-10 female members on their team, while 61 people report 4-10 male members on their team. Only 1 person reports 11-30 females on their team, while 6 respondents report 11-30 males on their team.

4.3.3 Team communication

Team members in the brigades generally communicate frequently. 56.5% of the respondents report that they communicate weekly or more frequent than weekly. Over 90% of the respondents communicate at least monthly.

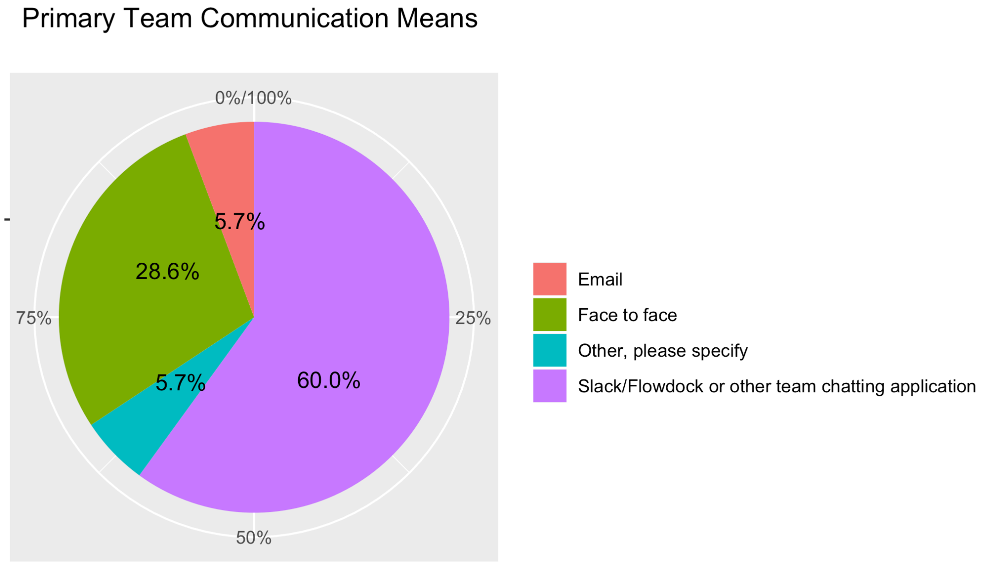


Figure 13: Primary Team Communication Means

Figure 13 shows the primary team communication means. Different than the "conventional OSS", which almost exclusively uses email, version control system and other electronic media to communicate (In early days of "conventional OSS", there might not be convenient team chatting applications such as Slack that can be used by OSS teams), civic OSS projects in CFA brigades rely more heavily on face-to-face communication and chatting applications, which are more spontaneous and less formal than emails or VCS used in “conventional OSS”. 60% of the respondents report that they primarily communicate through chatting application while 28.6% of the respondents primarily communicate face to face. It reflects the fact that they are co-located and their communications involve more informal discussions. These communication means appeal to some participants’ motivations of sharing knowledge, hanging out with like-minded civic hackers, and gaining reputation within the community. They also facilitate solving implementation issues of the projects.

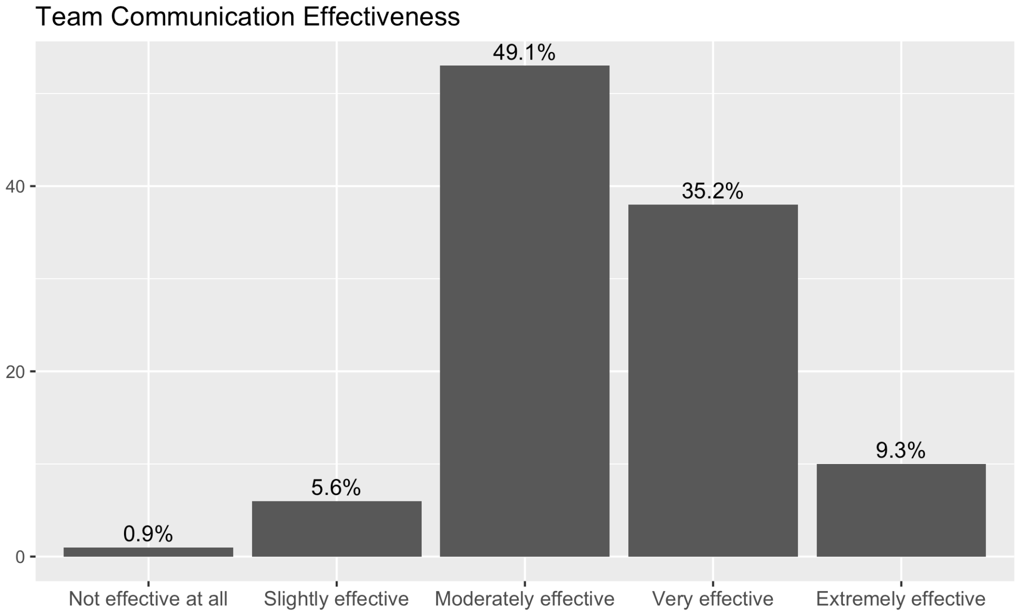


Figure 14: Team Communication Effectiveness

From the Figure 14, it is observed that 49.1% of the respondents think that their teams have moderate effectiveness in their communications, while 35.2% of the respondents report that their teams communicate very effectively.

4.4 Software engineering practices

4.4.1 Team-partner/user communication

For projects that have a government or community partner, we ask respondents to rate the effectiveness of the communications between the team and the partner. Results are shown in Figure 15. As we review in the literature, involvements of partners are important to the success of the projects. Our result shows that, the majority of respondents consider their communications with partners moderately or very effective.

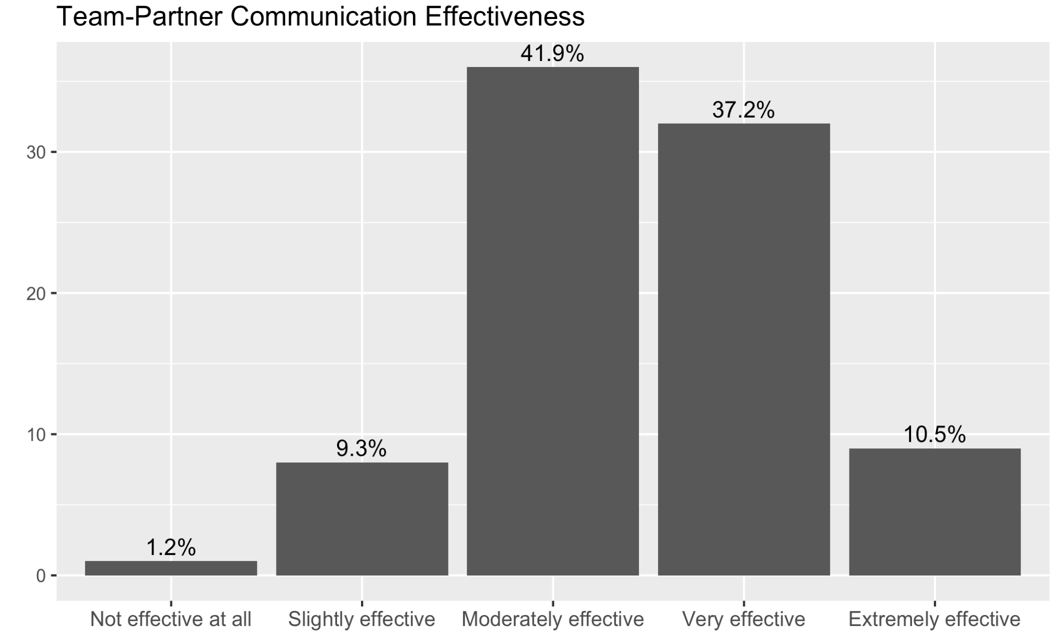


Figure 15: Team-Partner Communication Effectiveness

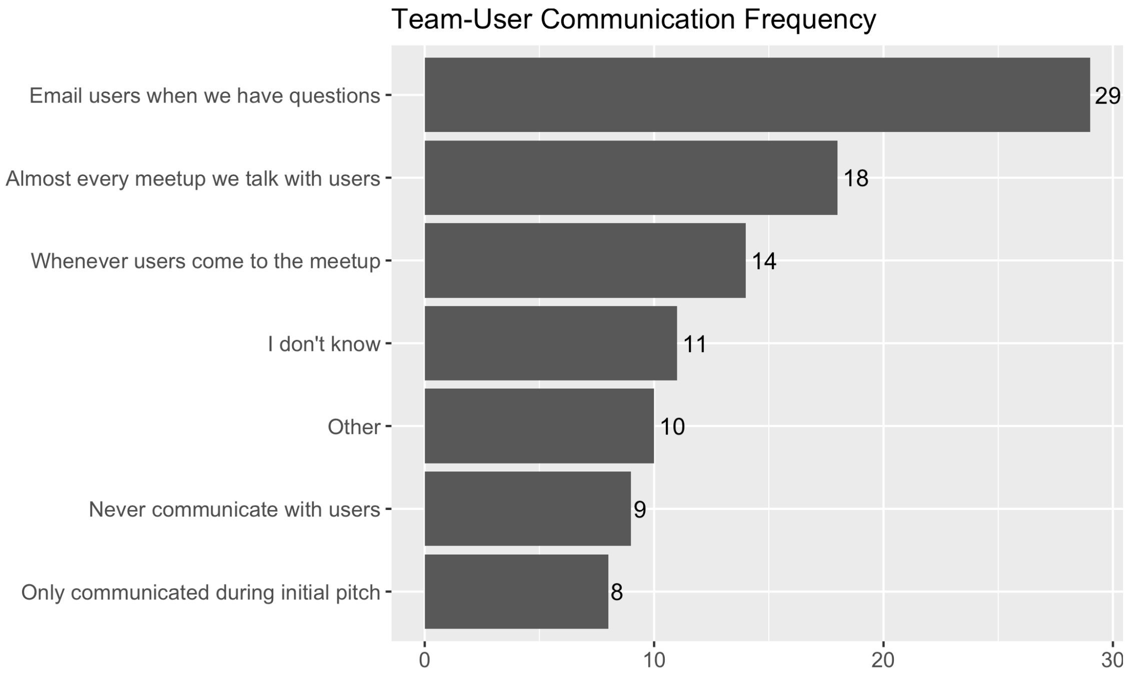


Figure 16: Team-User Communication Frequency

As for the frequency of the communications between the team and the target users ("users" include organizational partners and individuals who will use the application), 29 respondents email users whenever they have questions regarding the requirements. 18 respondents indicate that their target users come to the meetups every time and they talk in the meetup, while 14 respondents indicate that they talk to their target users whenever they show up in the meetup. Among all the respondents, 17 never communicate with users or only communicate with them during their initial pitch of the idea, which indicates that the team asserts the requirements with their personal experience or knowledge of the users. This is consistent with what researchers have discovered for the OSS requirement elicitation. In the free form answers, one member indicates that users are part of the development team and they communicate constantly. Another member reports that they respond to users' requests of features and bug reports via the project's Facebook page.

4.4.2 Requirement elicitation

Requirement engineering is an important part of the entire software engineering process. The methods of requirement elicitation used in CFA brigade projects are shown in Figure 17. The highest vote - 68 (66.2%) out of all respondents, suggests that a common practice for them is to use general knowledge to come up with the requirements, which is consistent with what the literature reveals for "conventional OSS". The next two major methods they use are interviewing stakeholders and holding meetings with target users. What respondents report in the free form answers suggest that they also use social media to interact with target users, or even integrate users into the project development.

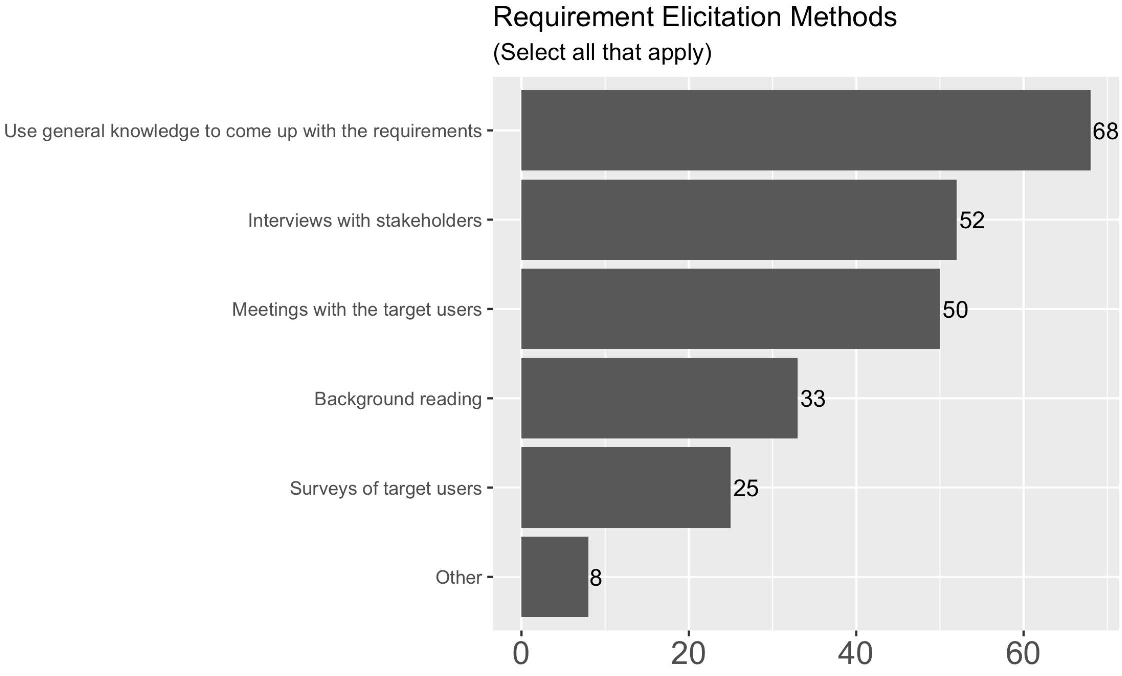


Figure 17: Requirement Elicitation Methods

Asserting the requirements may lead to potential problems for software development later on. However, due to the limited resource and voluntary nature of the developers and the organizational partners, it is inevitable to assert some requirements when partners are not available or target users are hard to reach out to.

When it comes to how the requirements are recorded, 33.8% of the participants report that they document requirements as user stories in natural language, 23.4% of the respondents use Waffle board or some other tools to record the features of the application, 21.8% of the respondents use prototypes to illustrate the requirements, 5.6% of the respondents choose “Use case diagram”, a few free form answers indicate that they use github issues to record the requirements, and 9.9% of the respondents report that requirements are not recorded at all. These results reveal that civic OSS projects in CFA brigades generally adopt an informal requirement documentation process. Natural languages describing the use cases, Waffle board, and prototypes that specify requirements are the major means of the requirement documentation. Little effort is invested in formal requirement specifications.

4.4.3 Partner’s involvement

As we review in the literature, the earlier the partner is involved, the more likely the partner is going to use the application. In terms of the project phase when the partner initially gets involved in the projects, 70.6% of the respondents report that it is during the requirement elicitation phase, 20.6% of the respondents report that it is during design phase. There are 9% of the respondents reporting that the partner is initially involved during implementation, testing or release phase of the projects.

As for how often the partner is involved in the project, the results are dispersed. From Table 4, we can see that most of them range from once a week, to less than once a month.

Frequency	%
Less than once a month	22.5%
Once a month	17.5%
Once in two weeks	18.8%
Once a week	26.2 %
Twice a week	1.25 %
More than twice a week	5%
I don't know	8.8%

Table 4: Partner's Involvement Frequency

The involvement of partners during the initial requirement elicitation helps steer the direction of the software application. Although the frequency of the partner’s involvement varies, about 69% of the projects meet every month or more frequent than every month. Considering that most brigades meet weekly, or every other week, the involvement of partners is quite frequent.

4.4.4 Software design

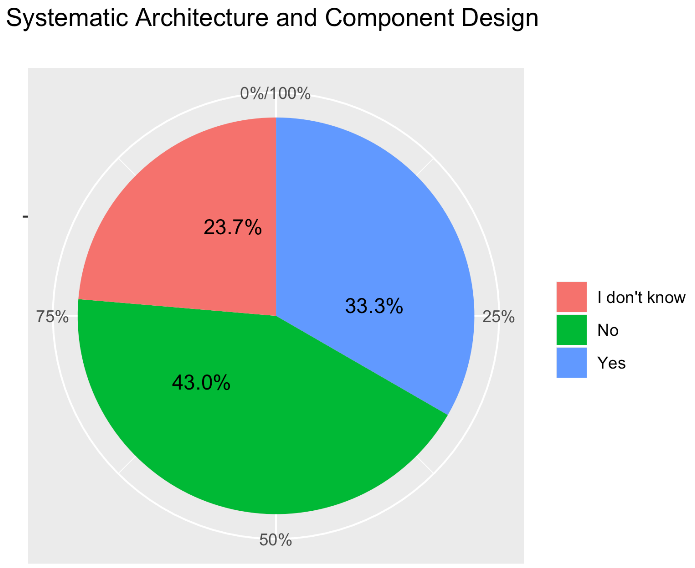


Figure 18: Systematic Architecture and Component Design

43% of the respondents report that their projects do not have a systematic architecture or component design. We further retrieve the responses only from developer respondents in that UI designer, tester, or project manager might not have idea about the architecture design. Results are shown in Table 5. Nearly half of the developers report that they do not have a systematic architecture or component design. And 19.2% of them do not know if there is a systematic design.

	No	Yes	I don't know
Developer	48.1%	32.7%	19.2%

Table 5: Developers' Knowledge of the Architecture and Component Design

The absence of extensive architecture design fits most of the software applications in CFA brigades, although the ideal characteristics of an architectural design should consider scalability, high cohesion and low coupling [15]. From our observations in Code for Denver/Boulder and the *civic tech* project repositories [52], most of the projects are web or mobile applications targeting at local community users rather than developer users, which is also proved in our survey results shown in Figure 7. Therefore, most of the projects simply use the existing popular MVC (model-view-controller) architecture, or do some customization based on existing MVC pattern. In addition, since the applications focus on local community, they do not have a very large user base, and scalability and maintenance is not highly prioritized. This leads to little extensive architecture design.

When it comes to whether the projects have documented interface design, 57% of the respondents report that they have wireframes or prototypes to document their user interfaces. 36.6% of the respondents indicate that they do not have these documented user interfaces.

4.4.5 Task assignment

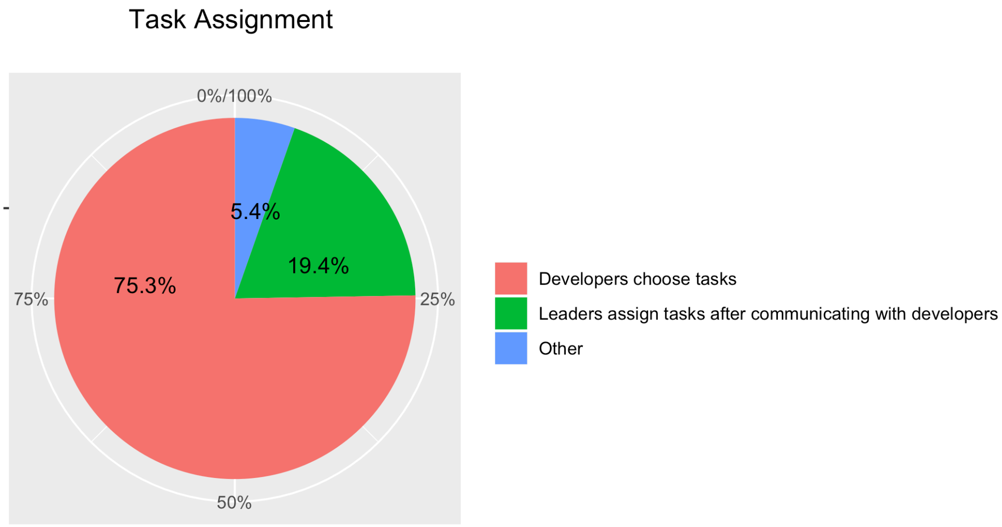


Figure 19: Task Assignment

Consistent with the “conventional OSS”, the civic OSS development also witnesses tasks taken by developers themselves. 75.3% of respondents give this feedback. 19.4% of them report that project leaders assign tasks after communicating with developers.

4.4.6 Development centrality

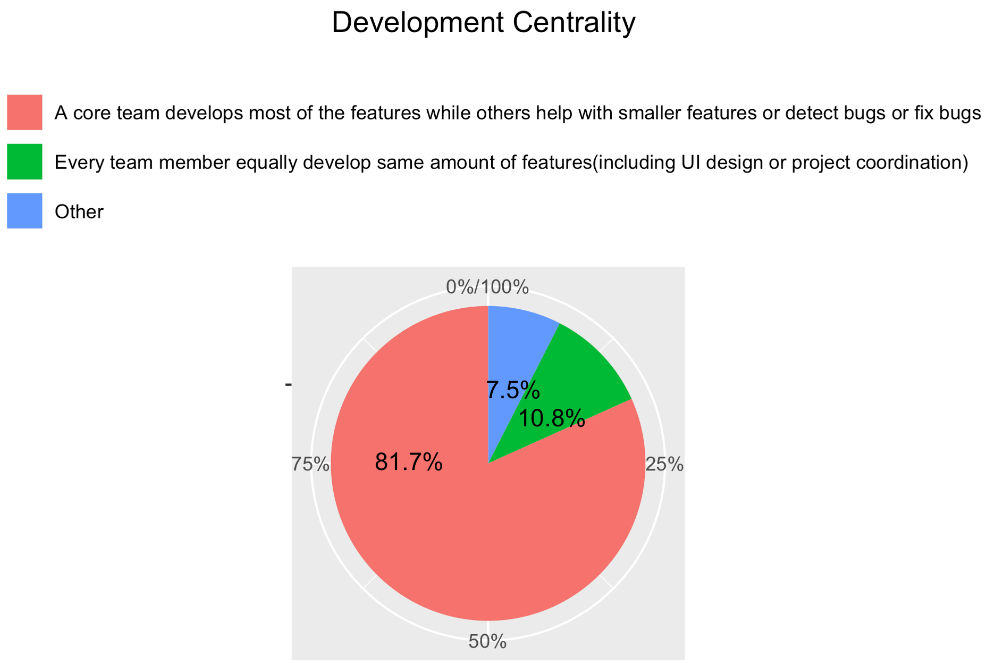


Figure 20: Development Centrality

The results of the development centrality among team members are also consistent with the “conventional OSS”. 81.7% respondents report that a core team develops most of the features while others help with bug detection, documenting or peripheral feature development. In the free form answers, 3 respondents report that everyone is equal in that they all contribute according to their skills or what are assigned to them. A few respondents report that they have a strong mixture of active and inactive developers. And a few respondents report that they are at initial planning phase and have not had any experience with the distribution of contributions at the time of taking this survey.

4.4.7 Project progress rate

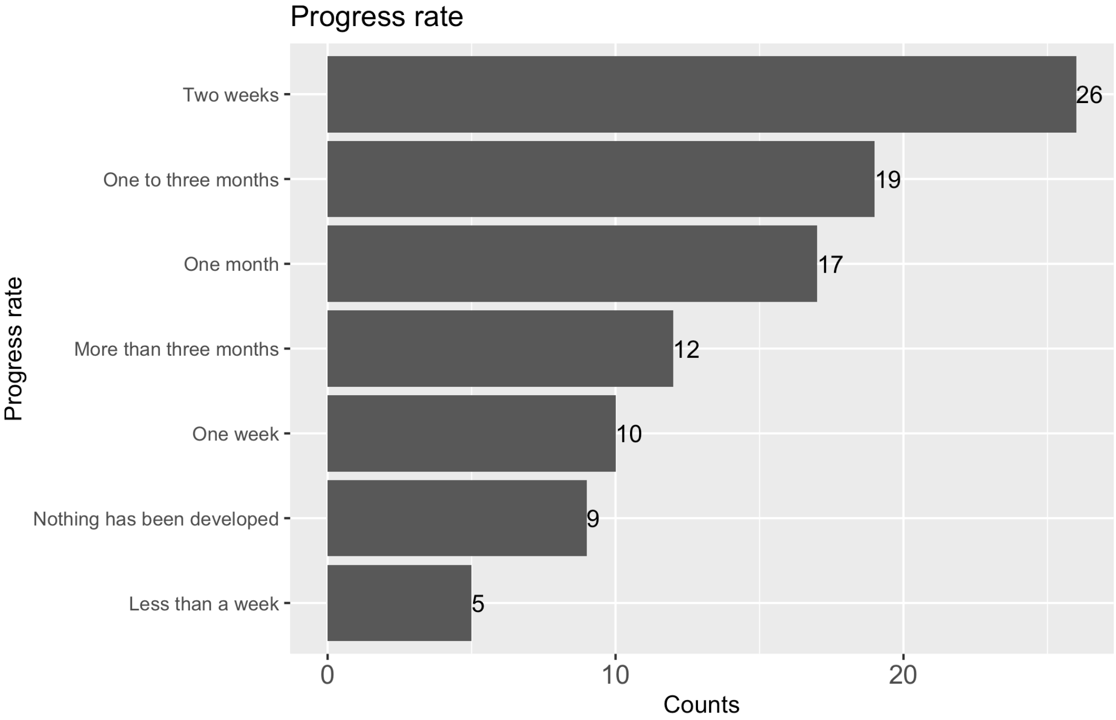


Figure 21: Progress Rate of Project

Our data provides a good overview of the progress efficiency. The progress rates for the projects vary, ranging from less than one week to more than three months. 26 out of 98(26.5%) respondents report that they make good progress in two weeks, while 9 (9.2%) respondents report that nothing is developed in the project yet. This maybe due to the initial phase their project is in.

4.5 Conceptual model, hypothesis test and prediction model

4.5.1 Variables and conceptual model

We convert our survey items to variables, group them into clusters and illustrate the key dimensions in civic open source software with a conceptual model.

Predictor factors (Explanatory variables):

Volunteer input: whether the volunteer is the end user of the application, the level of their interest in the technology being used in the application, whether the volunteer is a core member, their self-efficacy (the degree they think they can contribute to the application), and their participation level.

Project features: project size (the number of core team members), partner's involvement, and the level of public benefit of the project.

Team dynamics: whether the team is well led, gender composition of the team, the primary team communication means.

Intermediate measures (Explanatory variables):

Volunteer's perception: perception of whether the application will be completed or will be used, their team communication effectiveness.

Success measures (Response variables):

System creation: team member's satisfaction level, team member's willingness to continue in the project, and project progress rate.

We illustrate the potential relationships of the predictor factors, intermediate measures and success measures in the conceptual model in Figure 22.

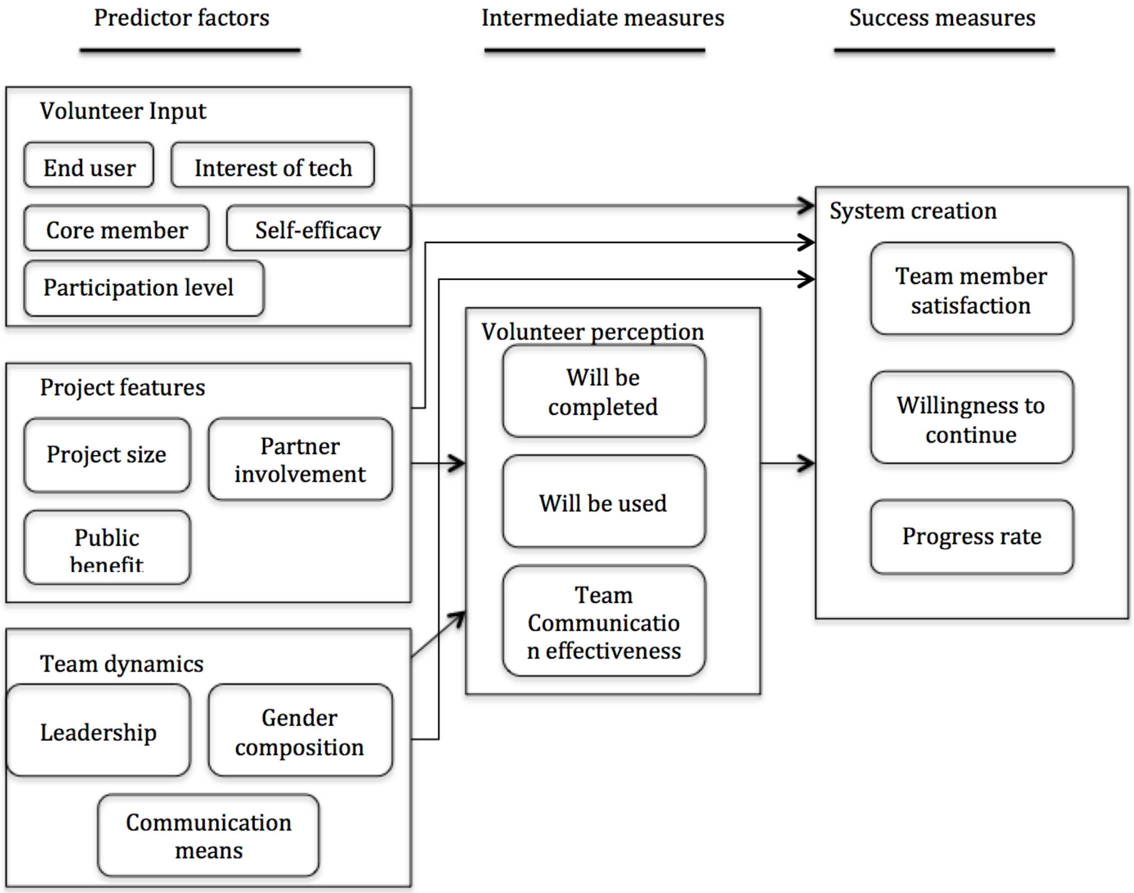


Figure 22: Conceptual Model of Variables

4.5.2 Hypothesis

Based on the literature and our observations, we form 11 hypotheses. We use the Spearman's rank correlation, simple linear regression, and Fisher's Exact test to test them on the imputed data sets separately and combine the results. The hypotheses and results are as follows.

H1. *Team member's participation level and willingness to continue in the project are not independent of him/her being an end user.*

The range of the p-values of our Fisher's exact tests between the team member's category of being an end user or not and the team member's participation frequency is from 0.009 to 0.03. The upper bound of the p-value is smaller than the critical value 0.05, indicating the significance of the evidence. It suggests that team member's participation frequency is dependent of him/her being an end user of the application. However, our result fails to provide evidence that the team member's willingness to continue in the project is dependent of him/her being an end user of the software project that he/she participate in, with the p-values ranging from 0.18 to 0.67. The lower bound of this range is greater than our critical value 0.05, indicating the lack of evidence against the null hypothesis. Figure 23 and Figure 24 show the heat map of the data points — End User versus Participation Level and Willingness to Continue. The darker the color, the more frequent the data falls in that area.

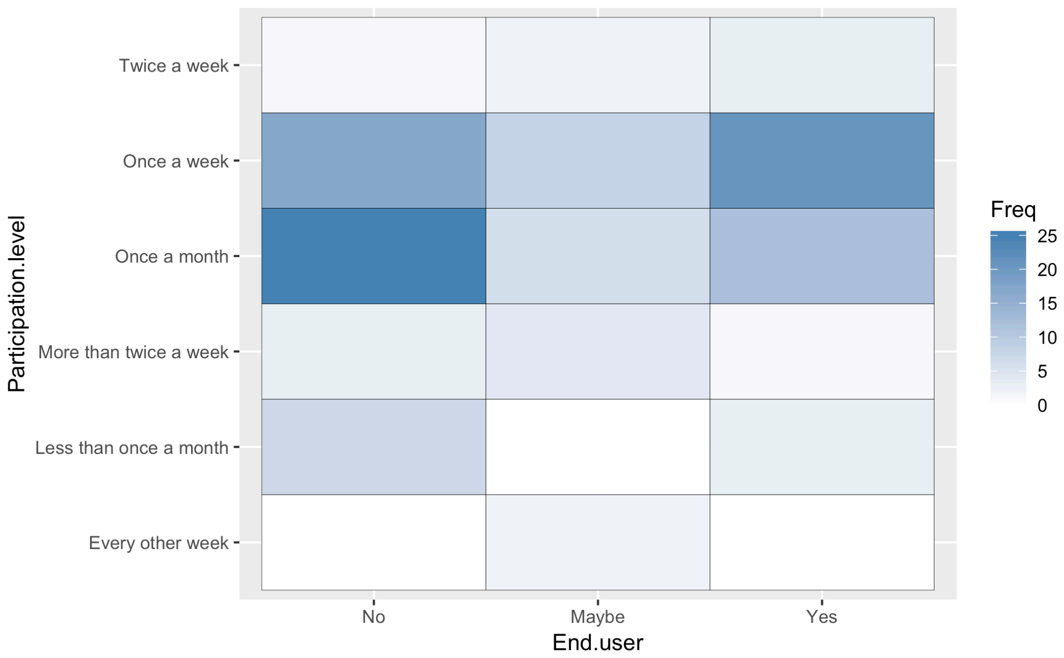


Figure 23: Relationship between "End.user" and "Participation.level"

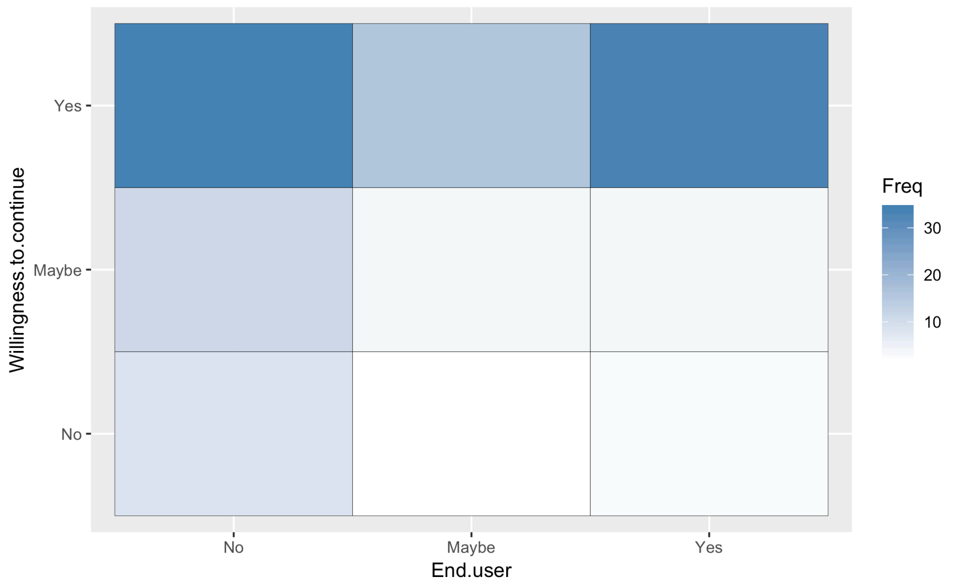


Figure 24: Relationship between "End.user" and "Willingness.to.continue"

H2. *Team member's satisfaction level and willingness to continue in the project are not independent of him/her being a core team member.*

It is proved that being a core team member or not is not independent of the team member's satisfaction level. The range of the p-values is from 1.95e-05 to 0.0004. The upper bound of this range is smaller than 0.05, indicating that the dependency between the pair of variables exists. It is also proved that being a core team member or not is not independent of the team member's willingness to continue in the project. The range of p-values is from 1.04e-05 to 7.62e-05. The upper bound of the range is smaller than 0.05, indicating the existence of dependency. Figure 25 and Figure 26 show the heat map of the data points — Core team member versus Satisfaction or Willingness to Continue.

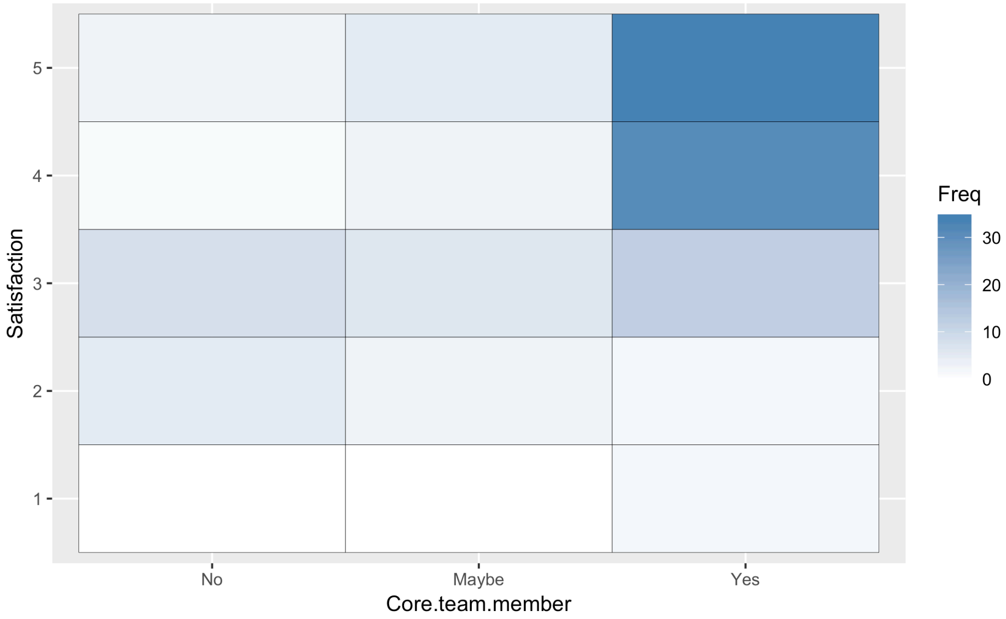


Figure 25: Relationship between "Core.team.member" and "Satisfaction"

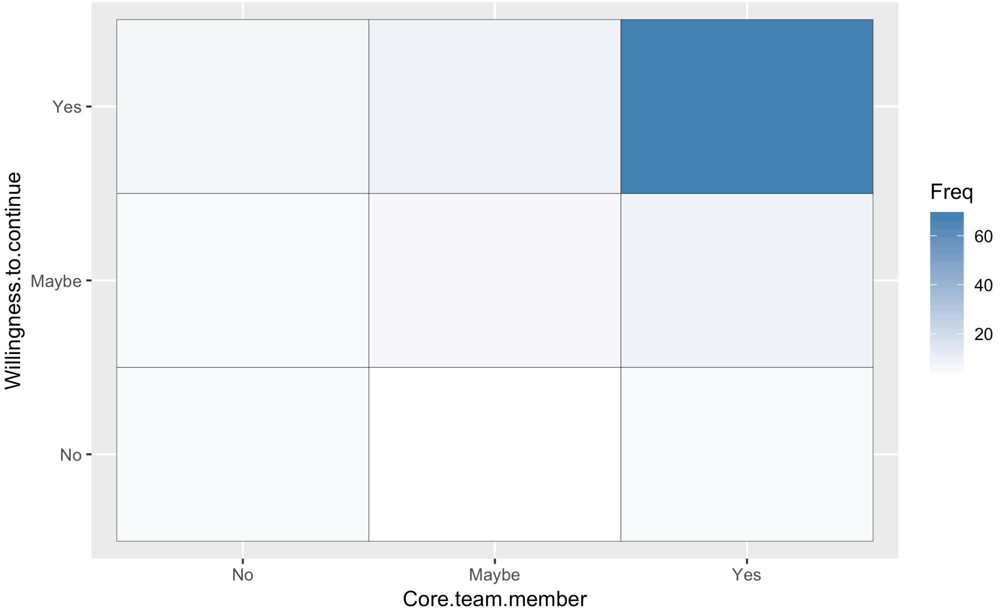


Figure 26: Relationship between “Core.team.member” and “Willingness.to.continue”

H3. *Team member’s perception of the project’s likelihood that it will be completed or will be used is not independent of the partner’s involvement.*

Our Fisher’s Exact test result does not show evidences that there is a dependency between the presence of a partner of a project and the volunteers’ perception that the project will be completed. The p-values range from 0.14 to 0.15. The lower bound of the range is greater than 0.05, which fails to reject the independence of the pair of variables.

However, the result of the test for the partner’s presence and the team member’s perception that the project will be used by target users indicates a dependency between the two variables. The p-values range from 0.0002 to 0.0013. The upper bound of the range is smaller than 0.05. Figure 27 and Figure 28 show the heat map of the data points — Partner.present versus “Will.be.completed” or “Will.be.used”.

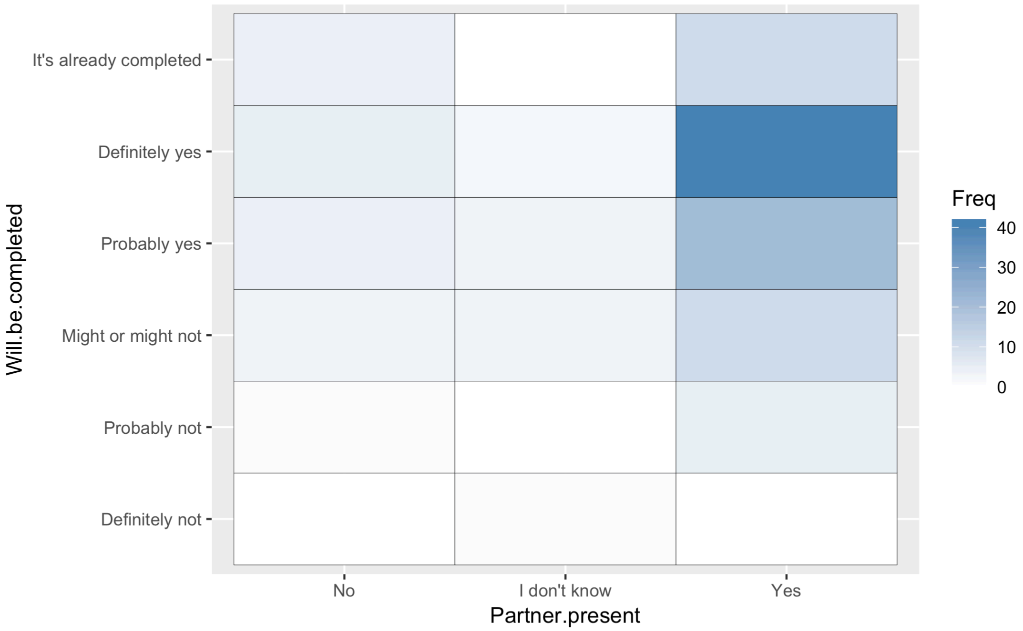


Figure 27: Relationship between “Partner.present” and “Will.be.completed”

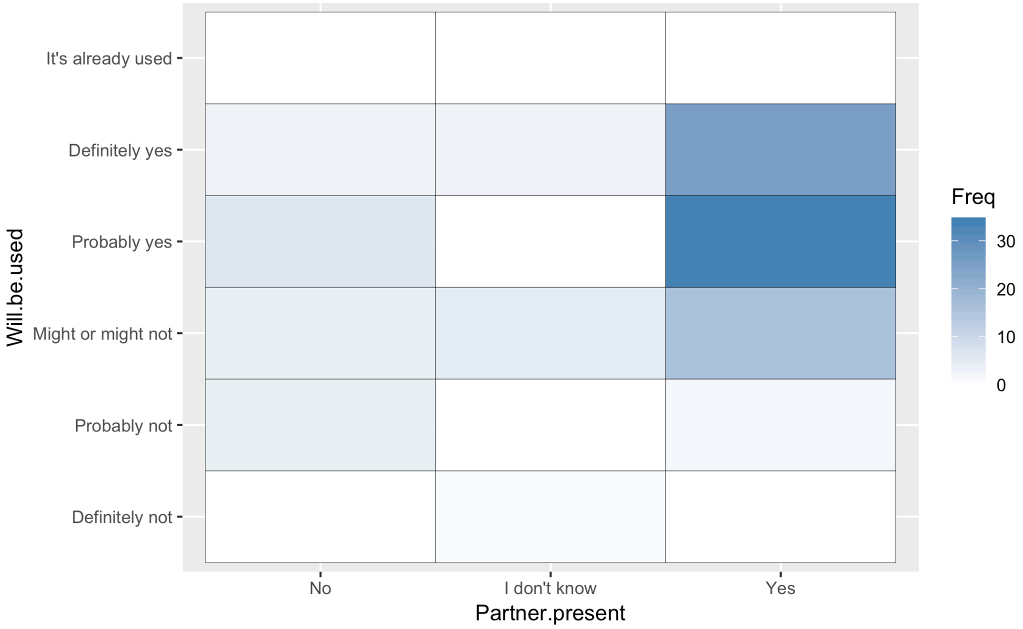


Figure 28: Relationship between “Partner.present” and “Will.be.used”

H4. *Team members' high interest in the technology used in the software application is correlated with high participation level and high willingness to continue.*

The result of Spearman's rank correlation coefficient fails to show a correlation between team members' interest in the technology and team members' participation level in the project. The average correlation coefficient is 0.116. To see how significant this averaged coefficient is, we regress the participation level on the team member's interest in the technology on 10 imputed data sets and get the pooled p-value 8.805658e-02 (> 0.05) according to Rubin's rules. However, our result shows evidence that team member's interest in the technology does correlate to his/her willingness to continue in the project. The average correlation coefficient is 0.256, and the combined p-value based on linear regressions on the ranks of this pair of variables is 6.459888e-03, which is smaller than our critical value 0.05 and hence shows that the evidence is significant.

H5. *Team member's self-efficacy level (operationalized as the degree that he/she thinks he/she can contribute to the application) is positively correlated to his/her willingness to continue.*

The average correlation coefficient from our Spearman's correlation coefficient analyses is 0.354. The combined p-value based on linear regressions of this pair of variables is and 1.800383e-03 (< 0.05), which is significant and indicates that as the level of team member's self-efficacy increases, his/her willingness to continue in the project tends to grow stronger.

H6. *Team communication effectiveness is correlated with the project progress rate and satisfaction level.*

Our results show that as team communication becomes more effective, the project tends to make progress faster and the team member tends to be more satisfied with the project. The correlation coefficient between the team communication effectiveness and the project progress rate is 0.285. Based on the combined result of linear regressions on this pair of variables on 10 data sets, the pooled p-value is 2.508233e-04 (< 0.05), indicating a significant evidence of the positive correlation. The correlation coefficient for the Team communication effectiveness and the satisfaction level is 0.416. The pooled p-value from the combined result of the linear regressions on this pair of variables on 10 data sets is 3.244151e-04 (< 0.05), indicating the significance of the positive correlation as well.

H7. *Team size (operationalized as core team size) is positively associated with progress rate.*

Our result gives evidences that the progress rate is associated with the size of the team. The average correlation coefficient is 0.185. The combined result of linear regressions shows that the pooled p-value is 1.035558e-03 (< 0.05).

H8. *Since the highest motivation of volunteers' is "help the community", we propose that "public benefit" level is positively associated with team member's participation level and their willingness to continue.*

Our results do not show associations between the “public benefit” level of the project and the team member’s participation level. The correlation coefficient is -0.081. The pooled p-value is 0.25 (> 0.05), which is insignificant. In addition, our results do not show evidence that the “public benefit” level of a project is correlated to the team member’s willingness to continue. Although the correlation coefficient is 0.252. the combined result of simple linear regressions shows that the pooled estimate is 0.1566, the pooled standard error of the estimates is 0.0823, and the pooled p-value is 5.975516e-02 (> 0.05), failing to indicate the significance of the correlation.

H9. *Team member’s perception that the software will be used by target users is positively correlated to their willingness to continue and satisfaction level.*

The spearman correlation coefficient for the pair of variables “will be used” and “willingness to continue” is 0.246. However, the pooled p–value from the combined result of linear regressions on this pair of variables is 0.4911749 (> 0.05). It fails to show an evidence of the existence of the correlation between team member’s perception that the project will be used and his/her willingness to continue in the project.

Our result proves that there’s a strong positive correlation between team member’s perception that the project will be used and his/her satisfaction level. The correlation coefficient is 0.488. And the pooled p-value is 3.193897e-07 (< 0.05), which is significant.

H10. *The number of female team members is correlated with the team communication effectiveness.*

The average correlation coefficient between the two variables is 0.175.The pooled p-value is 2.321803e-05 (< 0.05), which indicates an association between the number of female members on a team and the team communication effectiveness.

H11. *The Leadership is correlated with the team communication effectiveness.*

Our results indicate that the leadership is positively correlated with the team communication effectiveness. The correlation coefficient is 0.311 and the pooled p-value is 5.593157e-03 (< 0.05). The better the team is led by its leader(s), the better the team communication tends to be.

4.5.3 Logistic regression model

We want to develop models for the prediction of the progression rate of the project, participants' willingness to continue and their satisfaction level. Modeling of the success patterns of civic OSS is essential for better planning, organizing, and practicing the development process.

Through Logistic regression, we examine the factors associated with the participants' satisfaction level, their willingness to continue and the progress rate of the project. We also examine the significance of those explanatory variables.

Since our success measures— participants' satisfaction level, their willingness to continue and the progress rate of the project, are all ordered categorical variables, we use ordinal logistic regression to perform the analysis.

First, we report the distribution of respondents' satisfaction level of the projects and our results of Logistic regression for their satisfaction level.

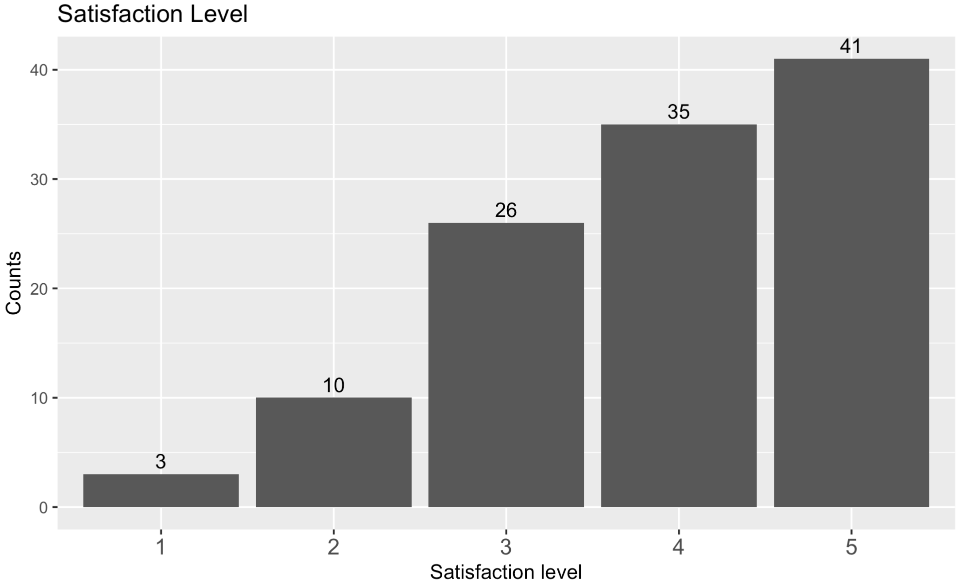
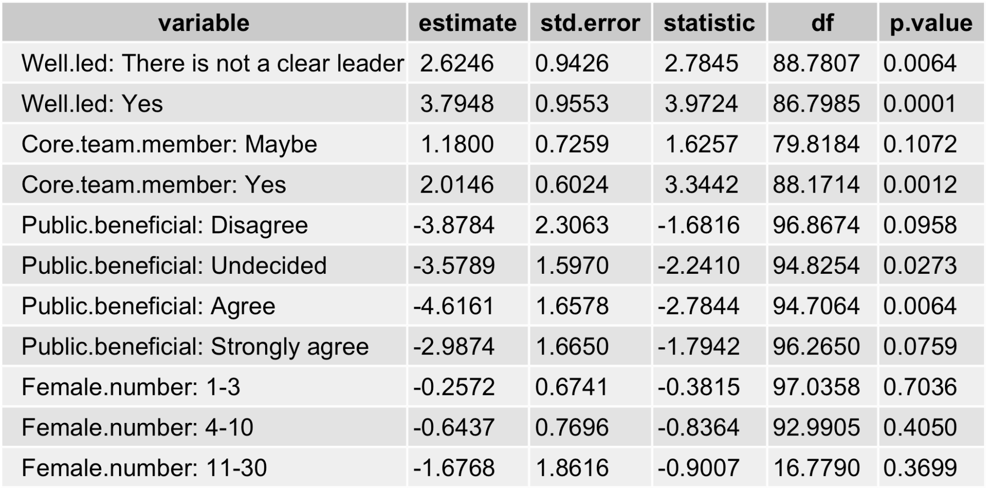


Figure 29: Satisfaction Level

Figure 29 shows the distribution of satisfaction rating of our respondents. Our sample has an increasing pattern regarding the satisfaction ratings. To develop a regression model, based on literature, previous analysis and our observations, we try independent variables including "Interest of tech", "Core team member", "Well led", "Public beneficial", "Will be used", and "Female number". We run regressions on ten imputed data sets. For all variables that are suitable to run with the regression, we get the following combined results of coefficients and related statistics shown in Table 6.

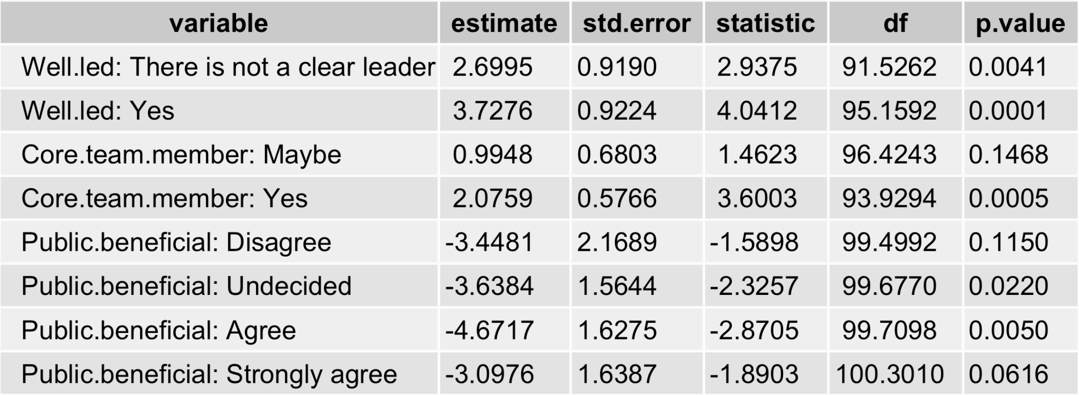


variable	estimate	std.error	statistic	df	p.value
Well.led: There is not a clear leader	2.6246	0.9426	2.7845	88.7807	0.0064
Well.led: Yes	3.7948	0.9553	3.9724	86.7985	0.0001
Core.team.member: Maybe	1.1800	0.7259	1.6257	79.8184	0.1072
Core.team.member: Yes	2.0146	0.6024	3.3442	88.1714	0.0012
Public.beneficial: Disagree	-3.8784	2.3063	-1.6816	96.8674	0.0958
Public.beneficial: Undecided	-3.5789	1.5970	-2.2410	94.8254	0.0273
Public.beneficial: Agree	-4.6161	1.6578	-2.7844	94.7064	0.0064
Public.beneficial: Strongly agree	-2.9874	1.6650	-1.7942	96.2650	0.0759
Female.number: 1-3	-0.2572	0.6741	-0.3815	97.0358	0.7036
Female.number: 4-10	-0.6437	0.7696	-0.8364	92.9905	0.4050
Female.number: 11-30	-1.6768	1.8616	-0.9007	16.7790	0.3699

Table 6: Results of Initial Regression for Satisfaction[3]

From the p-values in Table 6, we can see that the p-values of three groups of "Female number" are all greater than 0.05.Therefore we drop those variables to refine our model until we find a set of variables that have at least one significant p-value. The results are in Table 7.

[3] The estimates are drawn by using the "pool" function of the MICE package. The "pool" function combines estimates by Rubin's Rules.



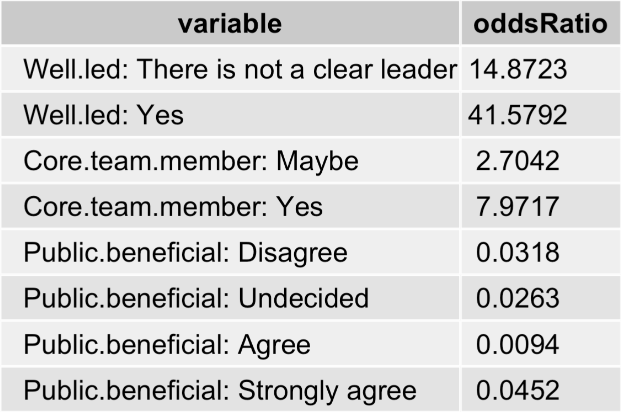
variable	estimate	std.error	statistic	df	p.value
Well.led: There is not a clear leader	2.6995	0.9190	2.9375	91.5262	0.0041
Well.led: Yes	3.7276	0.9224	4.0412	95.1592	0.0001
Core.team.member: Maybe	0.9948	0.6803	1.4623	96.4243	0.1468
Core.team.member: Yes	2.0759	0.5766	3.6003	93.9294	0.0005
Public.beneficial: Disagree	-3.4481	2.1689	-1.5898	99.4992	0.1150
Public.beneficial: Undecided	-3.6384	1.5644	-2.3257	99.6770	0.0220
Public.beneficial: Agree	-4.6717	1.6275	-2.8705	99.7098	0.0050
Public.beneficial: Strongly agree	-3.0976	1.6387	-1.8903	100.3010	0.0616

Table 7: Results of Refined Regression for Satisfaction[4]

The results indicate that a strong leadership of the project, the team member's identification as a core member, and the public benefit level of the project are significant predictors for the team member's satisfaction level. It is worth noting that after we refine our model by selecting variables according to their p-values, the p-values of those variables in the refined model are biased downward. Therefore, this selected model is indicative of possible relations among the variables, rather than verified relations among the variables.

We convert the coefficients to odds ratios. The result is shown in Table 8.

[4] The estimates are drawn by using the "pool" function of the MICE package. The "pool" function combines estimates by Rubin's Rules.



variable	oddsRatio
Well.led: There is not a clear leader	14.8723
Well.led: Yes	41.5792
Core.team.member: Maybe	2.7042
Core.team.member: Yes	7.9717
Public.beneficial: Disagree	0.0318
Public.beneficial: Undecided	0.0263
Public.beneficial: Agree	0.0094
Public.beneficial: Strongly agree	0.0452

Table 8: Odds Ratios of Regression for Satisfaction

As for whether a project is well led or not, compared to the reference group – “Not well led”, the odds of having a higher satisfaction rating for “There is not a clear leader” is 14.87 times greater, and the odds of having a higher satisfaction rating for a “well led” project is 41.58 times greater.

When it comes to how being a core team member predicts his/her satisfaction rating, compared to the reference group –“Not a core team member”, the odds of having a higher satisfaction rating for those who are core team members is 7.97 times greater.

As for how “Public.beneficial” predict the satisfaction level of team members, to our surprise, the estimates of coefficients are negative and odds ratios are less than 1, indicating that project with higher level of “Public.beneficial” is less likely to have higher level of satisfaction among team members. As we can see from Table 7, “Public.beneficial: Undecided” and “Public.beneficial: Agree” are significant. Referring to Table 8, compared to the reference group – “Public.beneficial: Strongly disagree”, the odds of having a higher satisfaction rating for those who are not decided on the project’s level of public benefit is 0.026 times greater. In other words, it is less likely to have higher satisfaction levels for those who are undecided on the project benefit level comparing to those who strongly disagree that the project is beneficial to the public. For those who agree that the project has public benefit, the odds of having higher satisfaction rating is 0.009 times greater, compared to those who strongly disagree that the project is beneficial to the public. In other words, team members who agree that the project is beneficial to the public experience a decrease in the odds of having higher satisfaction level, compared to those who do not think the project has public benefit.

Next, we report the distribution of respondents' willingness to continue their participation in the projects and our results of Logistic regression for their willingness to continue in the project.

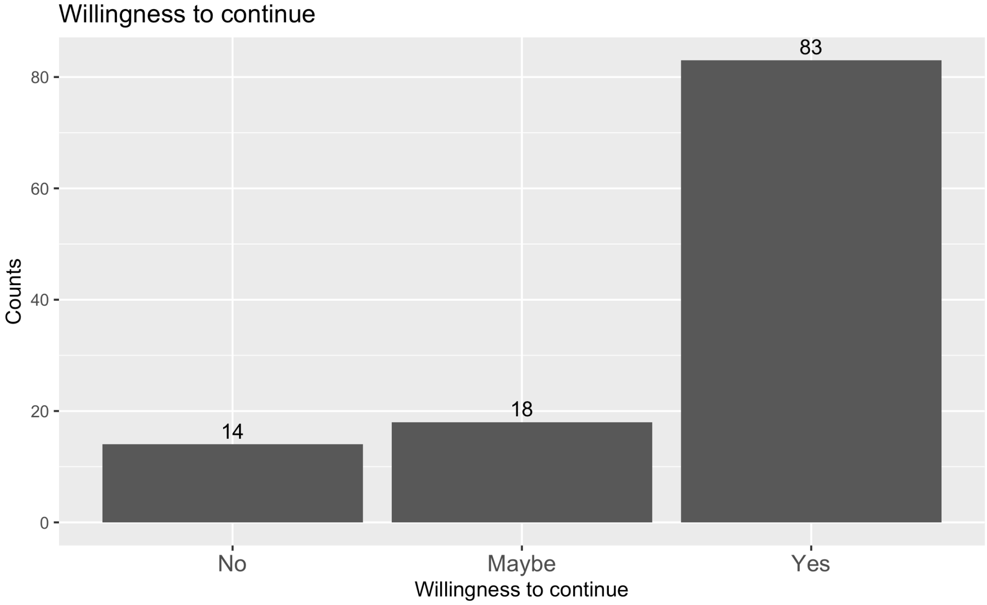
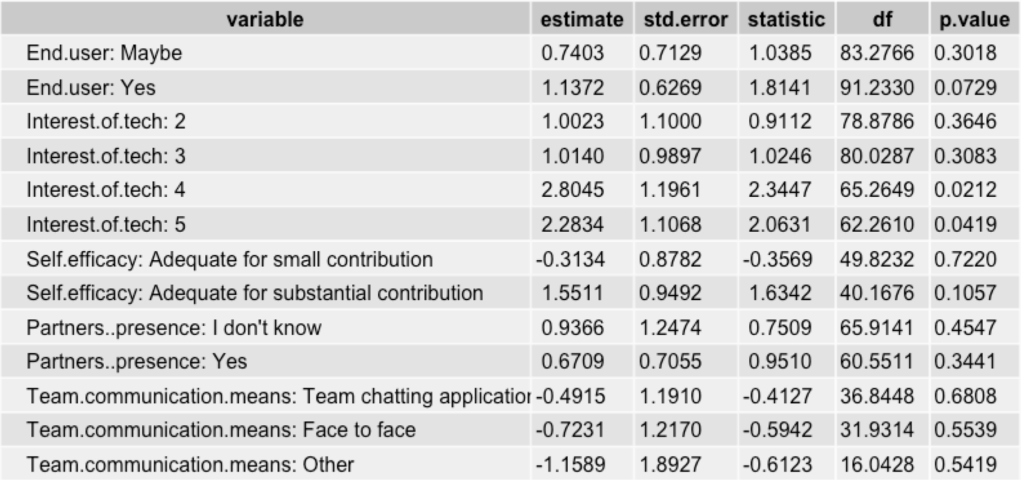


Figure 30: Willingness to Continue

Figure 30 shows the distribution of respondents' willingness to continue in the project. We run regression on explanatory variables including "End user", "Interest of tech", "Self efficacy", "Partner's involvement", "Public benefit", "Team communication means", and "Female number". The combined results of regressions on imputed data sets are shown in Table 9.

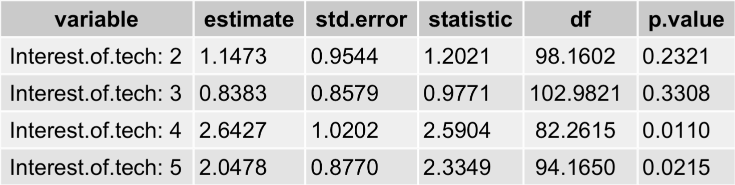


variable	estimate	std.error	statistic	df	p.value
End.user: Maybe	0.7403	0.7129	1.0385	83.2766	0.3018
End.user: Yes	1.1372	0.6269	1.8141	91.2330	0.0729
Interest.of.tech: 2	1.0023	1.1000	0.9112	78.8786	0.3646
Interest.of.tech: 3	1.0140	0.9897	1.0246	80.0287	0.3083
Interest.of.tech: 4	2.8045	1.1961	2.3447	65.2649	0.0212
Interest.of.tech: 5	2.2834	1.1068	2.0631	62.2610	0.0419
Self.efficacy: Adequate for small contribution	-0.3134	0.8782	-0.3569	49.8232	0.7220
Self.efficacy: Adequate for substantial contribution	1.5511	0.9492	1.6342	40.1676	0.1057
Partners..presence: I don't know	0.9366	1.2474	0.7509	65.9141	0.4547
Partners..presence: Yes	0.6709	0.7055	0.9510	60.5511	0.3441
Team.communication.means: Team chatting applicatio	-0.4915	1.1910	-0.4127	36.8448	0.6808
Team.communication.means: Face to face	-0.7231	1.2170	-0.5942	31.9314	0.5539
Team.communication.means: Other	-1.1589	1.8927	-0.6123	16.0428	0.5419

Table 9: Results of Initial Regression for Willingness to Continue[5]

We ask our respondents the level of their interests in the technologies being used in the project. The Likert scales are from 1 to 5. "1" is very uninterested, while "5" is very interested. The reference group is "1" (very uninterested). As we can see from the table, all p-values except for "Interest.of.tech: 4" and "Interest.of.tech: 5" are greater than 0.05. To refine the model with only one predictor "Interest.of.tech", we get the following results in Table 10.

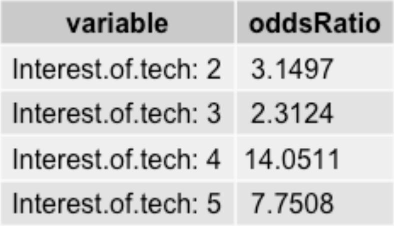
[5] The estimates are drawn by using the "pool" function of the MICE package. The "pool" function combines estimates by Rubin's Rules.



variable	estimate	std.error	statistic	df	p.value
Interest.of.tech: 2	1.1473	0.9544	1.2021	98.1602	0.2321
Interest.of.tech: 3	0.8383	0.8579	0.9771	102.9821	0.3308
Interest.of.tech: 4	2.6427	1.0202	2.5904	82.2615	0.0110
Interest.of.tech: 5	2.0478	0.8770	2.3349	94.1650	0.0215

Table 10: Results of Refined Regression for Willingness to Continue[6]

As shown in Table 10, two of the p-values are less than 0.05, which indicate the significance of those two levels of the predictor. The results indicate that strong interests of the technologies used in the project are significant predictors for the team member's willingness to continue in the project. Similar to our regression on team member's satisfaction level, the p-values of these two levels of variables in the refined model are biased downward after we drop other variables. This selected model is indicative of possible relations among the variables. We convert the coefficients to odds ratios. The result is shown in Table 11.



variable	oddsRatio
Interest.of.tech: 2	3.1497
Interest.of.tech: 3	2.3124
Interest.of.tech: 4	14.0511
Interest.of.tech: 5	7.7508

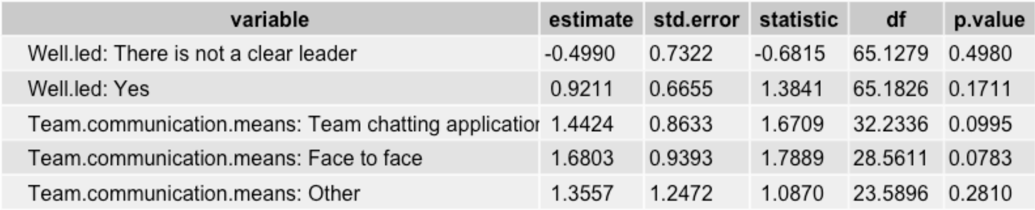
Table 11: Odds Ratios of Regression for Willingness to continue

Referring to Table 11, we observe that the odds of being more willing to continue in the project for those who are interested in the technologies used in the project is 14.05

[6] The estimates are drawn by using the "pool" function of the MICE package. The "pool" function combines estimates by Rubin's Rules.

times greater than that of those who are very uninterested in the technologies used in the project. Similarly, the odds of being more willing to continue in the project for those who are very interested in the technologies used in the project is 7.75 times greater than that of the reference group.

Lastly, to discover the predictors for the progress rate of the projects, we first run regression on variables including “Core team size”, “Well led”, “Team-partner communication frequency”, “Team communication means”. We drop “Core team size” and “Team-partner communication frequency” because they cause the over-fitting problem. We end up with the following results in Table 12.



variable	estimate	std.error	statistic	df	p.value
Well.led: There is not a clear leader	-0.4990	0.7322	-0.6815	65.1279	0.4980
Well.led: Yes	0.9211	0.6655	1.3841	65.1826	0.1711
Team.communication.means: Team chatting applicatior	1.4424	0.8633	1.6709	32.2336	0.0995
Team.communication.means: Face to face	1.6803	0.9393	1.7889	28.5611	0.0783
Team.communication.means: Other	1.3557	1.2472	1.0870	23.5896	0.2810

Table 12: Results of Initial Regression for Progress Rate[7]

From Table 12, it is observed that none of the variables are predictors with all their p values being greater than 0.05. Therefore, we cannot build a model that predicts the project progress rate based on the above factors that we are interested.

[7] The estimates are drawn by using the “pool” function of the MICE package. The “pool” function combines estimates by Rubin’s Rules.

Chapter Five: Limitations and Discussions

5.1 Response bias

5.1.1 Sample size

Limited access to inactive brigade members is an important reason for response bias. We distributed the survey by emailing the list of brigade leaders and also posted the survey in various brigade communication platforms, including the Slack channels (the major communication platform). The number of people (active or inactive) in the Slack channels of all brigades vary from about 30 people to more than 1500 people, suggesting that there might be a significant number of brigade members who have not seen this survey or they have seen this survey but do not take it. They might not want to take the survey because it is time-consuming for them, or they are not currently active, or they do not hold strong opinions on the projects in the brigade, or they have not participated in a software application project that they think is suitable for this study.

5.1.2 Representativeness

Locations of respondents

From the results in Chapter 4, we can see that responses from certain brigades are substantially more than those from some other brigades. A large number of observations are from Code for Denver. Although we sent the survey to 63 brigades across the United States, we only got responses from 37 brigades and a few from brigades not listed in our survey.

Roles of respondents

A large number of observations are reported by brigade captains/co-captains, as we can see from Figure 3 in section 4.1.2. The percentage of brigade captains/co-captains in our observations may not be consistent with the percentage of them in the actual brigade projects.

Projects of respondents' choices

It might be tempted to think that who respond to this survey are those who have participated in a relatively successful project, or at least an on-going project. But from our observations, many participants, especially those who have been involved for a long time, have experienced some unsuccessful or abandoned projects. And at the beginning of our survey, respondents are instructed to identify any project to answer the survey. Therefore, it is not fair to believe that they all identify successfully projects to answer the questions. They might also have a lot of thoughts on those unsuccessful projects that they want to report and base their answers on. In this case, we believe that there is some balance in terms of the project successfulness.

However, it is likely that those who are not satisfied with the projects have already left the projects and hardly have access to this survey, or simply do not take the survey. Therefore, it could be the potential reason of some unbalances in our data. The variance of opinions of the public benefit level of the project, satisfaction ratings or willingness to continue is relatively small. For example, few people report the project to be not beneficial to the public at all. And the distribution of respondents' satisfaction level is skewed to the higher levels. Some categories of some predictors have small or zero cells in the cross tabulations of the data. There could also be desires among respondents to provide socially desirable answers, which lead to this kind of skewed data distribution. This type of response bias introduces some issues with the logistic regression.

In short, the respondents of this study are those who have seen and are willing to take this survey, and the limited number of respondents who are inactive in the projects at the time of taking this survey indicates possible limited number of unsuccessful projects in our data. Therefore, the sample might not represent the CFA community as a whole and limits the generalizability of the results of this study.

5.2 Accountability

The respondents' understanding of the survey questions might differ from what we attempt to ask. For example, in one question, we ask respondents about their primary role in the project. Then in the next question, we ask them to choose all their roles in the project if they take multiple roles. The number of choices they are able to choose is not limited. However, we have seen some observations that choose "Brigade captain/co-captain" as their primary role but do not include this role in their answers to the question asking all the roles they take. It might be due to the gap of understanding of the questions between respondents and the survey designer. Respondents might think that they are not supposed to include their primary role again since they have just answered that question, or they think the number of items they can select is limited. So they just choose the other roles that they also take. Therefore, the accountability of these results might not reflect the reality.

5.3 Logistic regression model

In regression analysis for volunteer's satisfaction level, for variables like "Will be used" and "Interest of tech", we get a problem of over-fitting (complete separation of data points) when running the regression. Thus we drop them from the regression. However, there are still possibilities for the variable "Will be used" to predict the satisfaction level of a team member. It is proved that "Will be used" is correlated with "Satisfaction" (**H9**) in section 4.5.2. As we discussed in section 5.1, the problem is probably due to the limited amount and limited variation of the data used for this analyses. Although the sample is like this, from the previous analyses, literature review, and our observations in the brigades, we still consider that "Will be used" is a potential candidate as a predictor of team member's satisfaction level. More data needs to be obtained to test it.

It is observed that although "Self efficacy" is correlated with "Willingness to continue" (**H5**) as we analyzed in section 4.5.2, it is not a significant predictor in the regression for "willingness to continue". This is perhaps because of the "confounding bias”. A certain other variable influences both the “Self efficacy” and “Willingness to continue”. In other words, a certain other variable confounds the relation between “Self efficacy” and “Willingness to continue”. In this case when we have both that variable and “Self efficacy” in the regression, coefficients of “Self efficacy” might not be significant.

5.4 Success measures

There can be many success measures to assess civic OSS development. But we only choose three that are suitable in our case. We exclude some success measures for the following reasons. First, although we gather a lot of data about the application development practices, which are important explanatory variables for software quality, we do not use software quality to measure success of civic OSS in our study because the CFA projects are mostly ongoing, and it is hard to measure the software quality such as code quality or defect density under this circumstance. Therefore, we do not explore the relationship between development practices and software success in terms of quality. What’s more, we cannot use the number of team size as a success measure. Different than “conventional OSS”, which are normally pure online projects in which developers rarely meet, civic OSS focuses on solving local issues by local volunteers. Therefore, the size of community and the number of local technologists affects the size of the project team. Finally, since most projects are not released, users are hard to identify. So we cannot use user interest, user satisfaction, or number of downloads as success measures.

Chapter Six: Conclusion and Future Work

6.1 Conclusion

This study reveals that the top motivation of volunteers to participate in the civic software development is to help the community. The motives of voluntary action for social movements and community work, and motives of working in teams both apply to the participants of civic open source software development.

A majority of respondents joined the projects during initial planning phase. Nearly half of the developers report that they do not have a systematic architecture or component design. The core team size is mostly 1-6 people and most of the projects do not have a significant larger number of non-core contributors who help find problems or fix bugs. Project teams generally have more male than female members. The primary team communication means are chatting application and face-to-face. And most team members consider their communications moderately or very effective.

Most projects have a government/community partner. Team members tend to meet partners every month or more frequently. As for requirement elicitation methods, 66.2% of the respondents report that they use their general knowledge to come up with the software requirements, while “interview with stakeholders” and “meetings with the target users” are slightly less used.

Similar to conventional OSS, in civic OSS, developers choose tasks instead of being assigned tasks in their projects. And development work is significantly attributed to a small number of core contributors.

A conceptual model that captures the groups of variables is presented. The model includes clusters of explanatory variables such as volunteer input, project features, team dynamics and volunteers' perception of the project, and a group of success measures in terms of system creation, each of which contains multiple variables.

Our study shows that there is a dependency between team member's identification as an end user of the software and the team member's participation frequency in the project. Both of the team member's satisfaction level and his/her willingness to continue in the project are dependent of his/her identification as a core team member. We also find that the team member's perception that the software will be used by target users is dependent of the existence of a government/community partner for the project. The more likely that team members feel the project will be used, the more likely they will have higher satisfaction levels.

In addition, volunteer's interest in the technology used in the software development and his/her high self-efficacy level are correlated with his/her willingness to continue in the project as well. It is also proved that the better the team is led by a team leader, the more effectively the team members communicate. And the more effectively team members communicate, the more efficient that project makes progress and the more satisfied that team members feel.

Finally, our logistic regression shows that, leadership, team member's identification as a core team member, and the public benefit level of the projects are predictors for the satisfaction level of team members. Comparing to a project that is not well led, a well-led project or a project without a clear leadership has higher odds of having a higher satisfaction level. Compared to not being a core team member, being a core team member makes him/her have higher odds of being more satisfied with the project. Compared to volunteers who strongly disagree that a project is public beneficial, those who are undecided on the project's public benefit level or who agree that the project is public beneficial have lower odds of being more satisfied with the project. Our results also show that, compared to volunteers who are very uninterested in the technologies used in the project, those who are interested or very interested in the technologies experience an increase in the odds of being more willing to continue in the project.

6.2 Future work

Firstly, we would like to collect more data to make the results of this study more generalizable. The number and variance of observations is limited, which needs to be addressed by collecting more representative data to make the logistic regression fit better. Additionally, collecting more data from those who are not currently active in the projects can help get more insights into why people leave the projects and provide lessons for better management.

Secondly, we would like to study the development process in a qualitative way. Interviews will help provide a concrete and accurate description of the software development process currently adopted in the brigades. Some researchers, who have been core team members of the Apache server project, draft a good description of the development process and have it checked by other team members. As participants of CFA projects, we would like to interview brigade members or have them draft a description to provide a clear overview of the development process and find more insights.

Finally, a longitudinal study on the project level would help track the development trends, such as the change of team sizes, development practices, advancements of project, and team member's satisfaction levels. It may suggest other determinants of project success.

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Appendix: Survey questionnaire

1. Which brigade do you volunteer in? Code for _______

2. What’s your gender identity?
   Female
   Male
   Other

3. Are you currently active in the brigade?
   Yes
   No

4. How long were you or have you been involved in the brigade?
   Less than 3 months
   3-6 months
   6 months - 1 year
   1 – 2 years
   3-5 years
   More than 5 years

5. How often do you come to the meetups to contribute when you’re active in the brigade?
   Less than once a month
   Once a month
   Every other week
   Once a week
   Twice a week
   More than twice a week

(If you are currently involved in multiple projects, please identify for your self a representative project and base your responses on that to answer the questions; If you are not currently participating in the projects, please base your responses on the last project to which you contributed to answer the questions)

6. What do you identify as your primary role in the project? (select one)
   Front-end developer
   Back-end developer
   UX designer
   Product manager
   Testing

Documenting
Application partner
Brigade captain/co-captain
Brigade organization helper
Other, please specify ________

7. What are your roles in the project (if you have more than one role)? (select all that apply)
Front-end developer
Back-end developer
UX designer
Product manager
Testing
Documenting
Application partner
Brigade captain/co-captain
Brigade organization helper
Other, please specify ________

8. Are you also an end user of the project for which you're responding?
Yes
No
Maybe

9. I think this project will significantly benefit the public:
Strongly disagree
Disagree
Undecided
Agree
Strongly agree

10. What was the project status when you first joined the project?(choose all that apply)
Initial planning
Application User Interface Designing / Architecture designing
Implementation
Testing
Release
Maintenance

11. To what extent are you interested in the programming languages, frameworks or other technologies used by the project? (1 is very uninterested, 5 is very interested)
1

2
3
4
5

12. Are the projects well led by the project leader(s)?
Yes
No
There's not a clear leader in this project

13. Are there partners (government/NGO/individuals who are the target users) involved in the project?
Yes
No
I don't know

14. Do you think the project will be completed?
Definitely yes
Probably yes
Might or might not
Probably not
Definitely not
It is already completed

15. Do you think the project will be used by target users?
Definitely yes
Probably yes
Might or might not
Probably not
Definitely not
It is already completed

16. How many team members were in the project when you first joined it?
<3
3-6
7-10
11-20
<20

17. In an average month, how many members make substantial contribution to the code or design (i.e., core team)?
<3
3-6
7-10

11-20
<20

18. How many people help contribute to the project but are not the members of core team (for example, those who help discover defects, analyze requirements, publicize the application or communicate with end users)?
    0
    1-3
    4-10
    11-30
    >30

19. In an average month, how many females are in your whole project team(core plus non-core team)?
    0
    1-3
    4-10
    11-30
    >30

20. In an average month, how many males are in your whole project team (core and non-core team)?
    0
    1-3
    4-10
    11-30
    >30

21. How often do you communicate the requirements, implementation issues or progress with other team members?
    More than weekly
    Weekly
    Every Two weeks
    Monthly
    Every two to three months
    Less than every three months
    Never

22. What is your primary way of communicating the project with the team members?
    Face to face
    Email
    Slack/Flowdock or other team chatting application
    Other, please specify ________

23. How effective is your communication with other team members?
    Extremely effective
    Very effective
    Moderately effective
    Slightly effective
    Not effective at all

24. How effective is the communication between your team and the partner? (This question is only displayed to the respondent who select "Yes" to question number 13)
    Extremely effective
    Very effective
    Moderately effective
    Slightly effective
    Not effective at all

25. How does your team capture the requirements of the software application? (Choose all that apply)
    Interviews with stakeholders
    Surveys of target users
    Meetings with the target users
    Background reading
    Use our general knowledge to come up with or supplement the requirements
    Other, please specify ________

26. How often do you communicate with the users to confirm the requirements?
    Almost every meetup we talk with users about the requirements
    Whenever the users come to the meetup
    Email users whenever we have questions regarding the requirements
    Only communicated with users when they initially pitched the project idea
    Never. We use our general knowledge to come up with the requirements
    I don't know
    Other, please specify ________

27. How are the requirements recorded? (choose all that apply)
    Requirements are not recorded.
    User stories/ use cases statements in natural language
    Use case diagrams
    We use prototypes to illustrate the requirements
    We use waffle board or other tools to record the feature requirements of the application
    State transition diagrams
    Other, please specify ________

28. Is there a systematic software architecture or component design?
    Yes
    No
    I don’t know

29. Is there a documented user interface design (prototype/wireframe) in the project?
    Yes
    No
    I don’t know

30. When did the external partner first get involved in the project? (This question is only displayed to the respondent who select “Yes” to question number 13)
    Requirement elicitation phase
    Design phase
    Implementation phase
    Testing phase
    Release phase
    Maintenance phase

31. How is the partner involved in the project? (select all that apply)(This question is only displayed to the respondent who select “Yes” to question number 13)
    Communicate requirements and solutions face to face
    Test the features of the application
    Email
    Slack/Flowdock or other team chatting application
    Other, please specify ________

32. How often does the partner of the project get involved in the project? (This question is only displayed to the respondent who select “Yes” to question number 13)
    Less than once a month
    Once a month
    Once in two weeks
    Once a week
    Twice a week
    More than twice a week

33. How are tasks assigned to different developers?
    Developers choose tasks
    Project leader assign tasks after communicating with developers
    Other, please specify ________

34. What’s the time interval to release a new feature or have a substantial styling improvement?

Less than a week
One week
Two weeks
One month
One to three months
More than three months
Nothing is developed in the project

35. Are the functionalities of the application developed equally by all developers, or does a core team develop most of the functionalities?
Every team member equally develop same amount of features (including UI design or project coordination)
A core team develops most of the features while others help with smaller features or detect bugs or fix bugs
Other, please specify ________

36. Was the MVP (minimum viable product) of your project completed?
Yes
No
Will soon be completed
I don't know

37. Are you a core team member (make substantial contribution to the code or design)?
Yes
No
Maybe

38. What motivated you to participate? (choose up to 3)
Improve programming/UI design/project management skills
Solve your own problem
Want to help the community
Social activities (hang out with people)
Make career advancement
Gain reputation among the community
Share knowledge and skills
Help publicize my app and increase its usage
To get help in realizing a software application idea
Solve a problem that can't be solved by commercial product
Other, please specify ________

39. I feel that my level of skills to contribute to the project is:
Inadequate to contribute substantially
Adequate for small contribution

Adequate for substantial contribution

40. What are the reasons that you decided to stop contributing? (choose up to 3) (This question is only displayed to the respondent who select "No" to question number 3)
    I no longer have time to participate.
    I don't feel I have the right skills to contribute to the projects.
    The project became inactive.
    The projects were not of interest to me.
    I feel that the project goals might not be achieved.
    The projects do not have much civic benefits.
    The projects are already almost completed so I don't feel a need in participation.
    The atmosphere there is not inclusive enough.
    I can't get enough help when I encountered problems.
    It does not help with improving my skills/experience/career.
    I moved to another city.
    Other, please specify ________

41. If you have time, are you willing to continue (if you are active now) or return (if you are not active now) to contribute to the projects?
    Yes
    No
    Maybe

42. How do you rate your overall satisfaction of the project (1 is very unsatisfied, 5 is very satisfied)?
    1
    2
    3
    4
    5

43. Is there anything else you want to say about participating in the projects or the survey? _____________