VOLUNTEERS' PARTICIPATIVE BEHAVIORS IN OPEN SOURCE SOFTWARE DEVELOPMENT: THE ROLE OF EXTRINISIC INCENTIVE, INTRINISIC MOTIVATION AND RELATIONAL SOCIAL CAPITAL

by

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A DISSERTATION

IN

BUSINESS ADMINISTRATION (ISQS)

Submitted to the Graduate Faculty
of Texas Tech University in
Partial Fulfillment of
the Requirements for
the Degree of

DOCTOR OF PHILOSOPHY

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ACKNOWLEDGMENTS

I would like to thank the members of my dissertation committee: Dr. Donald Jones, Dr. Peter Westfall, Dr.Zhangxi Lin, and Dr. Robert McDonald, for their continuous support, encouragement, and suggestions. Specifically, I would like to express my sincere appreciation to Dr. Jones for his valuable advice and guidance in the whole process of my dissertation working. Without it, this dissertation would not be a reality.

I would also like to thank the Area of Information Systems and Quantitative Sciences at Rawls College of Business. I appreciate the faculty, staff and doctoral students for the support and help kindly offered by them.

I also wish to thank my parents, my wife, and my sister, whose mental, physical and spiritual supports are so important for my successful completion of the doctoral program. As the only son, I would like to thank my dear parents for all the encouragement, care and guidance that they sent to me from far away in China.

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ABSTRACT

Open source software is a revolution in software development and represents a new mode of software distribution. The widespread diffusion of Internet access in the early 1990s led to a dramatic acceleration of open source activity. Compared with traditional software development, open source software development is informally organized, loosely structured and lacks the formal control mechanisms used in traditional software development.

The success of an open source project depends on the participation of voluntary developers. Currently the research on open source software is focused on understanding the motivations or incentives for open source participation at general level. There has been very little research about the influence of community characteristics on the participants' behaviors. To better understand the motivations of open source participation, this study integrates incentive factor (reputation gaining, personal software needs, and learning purpose), intrinsic motivational factor (enjoyment) and social relational factors (identification and obligation) to see how these factors impact participation level in open source communities, and how they work together and complement each other.

An empirical study using Web survey methodology was conducted to test the research model. Data were collected from voluntary developers in many open source projects. Using the Structural Equation Modeling (SEM) method, data analysis showed that most of the research hypotheses were supported.

The research findings show that the relational social factors play very important role in motivation of open source project participation. Professional benefits and

enjoyment also have influence on participation. Virtual community quality is critical to the success of open source software development, and voluntary developers' participation can be promoted through community building, including member selection, goal congruence, promotion of interpersonal relationships, and providing work-related and emotional support. The research findings provide theoretical contribution to open source software research, and practical implications for open source project management.

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CHAPTER I

INTRODUCTION

1.1 Research Background

Open source software is a revolution in software development and represents a new mode of software distribution. Computer software is traditionally sold only as a finished product, or as precompiled binary code, with a license. Software users do not have access to the source code. Bug fixes and support are completely dependent on the organization that sells the software. By contrast, open source software is software that is licensed to guarantee free access to the source code, so users who are technically inclined can fix bugs or make modifications by themselves (Bretthauer 2002). The past decade has seen a marked expansion in the open source software movement.

The open source initiative starts from the ideology that software should be free and open. It can actually trace its roots back at least thirty years, when Richard Stallman developed the operating system GNU, which is free software. Stallman defined free software as possessing four essential freedoms: people have the freedom to run the program for any purpose; people have the freedom to modify the program to suit their needs; people have the freedom to redistribute copies, either gratis or for a fee; people have the freedom to distribute modified versions so that the community can benefit from the improvements. To protect his work from being taken and used in proprietary packages, Stallman developed the general concept of copyleft, and the GNU General Public License (GNU GPL).

The concept of copyleft is the core to open source software. To copyleft a program, the programmer, besides copyrighting the program to himself, also signs a General Public License (GPL) granting everyone the right to use, modify and distribute the program on the condition that the license also grants similar rights over the modifications he or she has made. Under this arrangement, everyone has free access to the program but it is protected from becoming someone's private intellectual property (Mustonen 2003). Copyleft is a device for linking the programmer and his contribution permanently together while also makes the contribution publicly observable. This creates an environment where talented programmers have an incentive to signal their abilities via the copyleft community.

The widespread diffusion of Internet access in the early 1990s led to a dramatic acceleration of open source activity. The Internet-based community provides an environment for developers to collaborate online. Open source software development is community-based with open membership; worker incentives and motivations shift from those of employees to those of volunteers, and unlike in a firm setting, there isn't an authority relationship to regulate the behavior of community members. The development team members are organizationally and geographically dispersed, linked through the Internet. Finally, the software-creation platform is based on a many-to-many, computer mediated communication technology (Lee and Cole 2003). These four characteristics make open source software different in organization structure from traditional software development.

The most important advantage of open source software development is that the knowledge is public. Because commercial software vendors typically wish to sell the

code they develop, they sharply restrict access to the source code of their software products. The consequence of this restriction is that only insiders have the information required to modify and improve that proprietary code. In sharp contrast, all are offered free access to the source code of open source software, which means that anyone with the proper programming skills and motivation can use and modify any open source software.

An open source software development project is typically initiated by an individual or a small group with an idea for something interesting that they themselves want for an intellectual or personal or business reason. The project initiators generally become administrators or maintainers who are responsible for the project management. Developers are usually individuals who have interests in the projects and voluntarily participate (von Hippel and Krogh 2003). For example, the most notable open source software, Linux, was created in 1991 by Linus Torvalds, who was motivated to pursue this project by intellectual curiosity. He built the kernel of a truly open source operating system, and retained clear leadership of the Linux project by authority of making the ultimate decisions. Now the Linux community contains hundreds of core developers and even more peripheral contributors.

Open source software attracts increasingly more attention from the software industry, because there are some successful open source programs which are widely used by commercial companies, government organizations and individual users. In addition to Linux (an operating system), other well-known open software systems include Apache (a web server), Mozilla (a web browser), and Perl (a web development tool). Today, there are numerous open source software projects operating on the Internet. On November 8, 2004, on sourceforge.net, the world's largest open source website, there were 90350

registered projects and 949,916 registered users. As more organizations use open source software in their information infrastructures, the competition between open source and proprietary software will intensify, and significantly impact the software industry.

Open source software is imposing increasingly significant influence on the software industry, and on society. Open source software has been adopted by more and more companies, government organizations and educational institutions. Many open source software, for example, Linux, has got commercial support from IT companies, and is growing faster than before. Currently the competition between open source and proprietary software is a hot issue for debate. Faced with the competition from Linux, Microsoft has to lower the price of some products, and changes its global pricing strategy. Some developing countries, like China, are planning to take advantage of open source software to break the monopoly of Microsoft and to promote their own software industry.

However, there has not been much academic research on open source software development, and many questions remain to be answered in this field. The research of open source software is related to multiple disciplines, including computer science, management and organization sciences, social sciences, psychology, economics and law (Gacek and Arief 2004). More academic research is needed for understanding the nature of open source software organization, development and progress.

1.2 Research Motivation and Research Questions

Open source software is different from proprietary software in that it takes a virtual community as its organization form, and developers are volunteers who are not formally organized as employees in businesses. Therefore, the organization for open

source software development is loosely structured, and generally speaking, self-organized. With the increasing popularity of open source software, there is an increased interest in understanding of open source software development, as well as its organization, process and characteristics. At present, among the numerous open source software projects, there are successful examples of software that started from small seeds of code, attracted voluntary developers into their communities, and eventually achieved widespread distribution. The most well-known ones like Linux, Apache, Mozilla and Perl are often cited as successful examples for open source software. At the same time, there have been even more open source projects that died before they ever reached maturity. Thus, it is important for both the software industry and the open source movement to better understand the characteristics of a successful open source community, and how these factors affect the outcome and viability of an open source software project.

According to Hoegl and Gemuenden (2001), the most critical factors to innovative projects are communication, coordination, balance of member contribution, mutual support, effort, and team cohesion. These factors are demonstrated to determine the project effectiveness and efficiency, and the psychological benefit of participants, which is usually reflected through work satisfaction, knowledge and skill learning. The nature of open source software development is an innovative process based on members' voluntary participative actions (Markus et al. 2000; Krogh 2003), so how to promote the success factors is important to the open source software projects.

Prior studies have investigated open source software from multiple perspectives, including organization, psychology, economics, and social sciences. These studies help us understand how open source software is developed and how the open source

community is organized and structured. However, currently the research on open source software is focused on understanding the motivations or incentives for open source participation at general level. It has been reported that both extrinsic factors (career expectation, reputation gaining, personal software needs, learning purpose) and intrinsic motivations (enjoyment, normative) influence open source participation. There has been very little research about the influence of community characteristics on the participants' behaviors, which are determinants to the successful outcome of an open source project.

Social relationships are important for the viability and success of community structures because they serve as the psychological ties to hold the members together and promote their participation (Wasko et al. 2004). Online community is a social structure because relationships can be developed among persons (Cummings et al. 2002; Kraut et al. 1999). There has been evidence that social capital can be generated from online interaction even without face-to-face meetings (Lin 2001; Wasko and Faraj 2005). Open source software development is collective action in online social environment. Social capital is important to facilitate collective actions and promote knowledge creation (Nahapiet and Ghoshal 1998). To better understand the participants' behavior and provide guidance for management of open source software projects, it is necessary to include factors from the social perspective in study of open source software and investigate the effects of social factors in the open source community.

Nahapiet and Ghoshal (1998) identified four aspects in relational social capital, which are identification, obligation, trust and norm. Identification and obligation represents the relational ties between an individual and the collective. They make an individual psychologically attached to the collective. There have been some studies in

physical organizations which show that an individual's identification with the organization and obligation to the organization induce prosocial behavior and motivate the individual act towards the collective goods of the organization (Wiesenfeld et al. 1999; 2001).

Open source software development is characterized by its unique organization form; it is developed by a virtual community of voluntary developers which are geographically dispersed and do not have formal affiliation to the developing team. Compared with traditional software development, open source software development is informally organized, loosely structured and lacks the formal control mechanisms used in traditional software development. The lack of formal control and coordination mechanisms creates a challenge in inducing volunteers to perform successful collective tasks because the participants' activities are mostly volitional based on their own initiatives. So individual motivations and social relational ties between the participants and the open source communities are expected to play a critical role in the success of an open source project through promotion of participative behaviors and continuance to the project.

Research on virtual community suggests that external incentives, intrinsic motivation and relational factors determine participative behaviors and knowledge contribution in virtual or online communities (Wasko et al. 2004; 2005). Currently, there has been no research which integrates the external, intrinsic and relational factors to investigate their effects on the voluntary participative behaviors in open source context. To better understand the motivations of open source participation, this study integrates incentive factor (reputation gaining, personal software needs, and learning purpose),

intrinsic motivational factor (enjoyment) and social relational factors (identification and obligation) to see how these factors impact participation level in open source communities, and how they work together and complement each other. To understand the motivational factors in more depth, it is important to conduct study at community level and know the community characteristics that may affect the motivational factors, and eventually impact the developers' participation.

The results of the study are expected to help better understand developers' behavior in open source software communities, and to provide guidance for open source software project leaders on how to effectively manage and administer the projects.

The specific research questions are:

1) What is the role of external incentive, intrinsic motivation and social relational capital in open source software development?
2) Do reputation gaining, enjoyment and relational factors increase participative behavior in open source community?
3) What factors lead to enjoyment in an open source community?
4) What factors lead to social identification with an open source community?
5) What factors lead to social obligation to an open source community?

1.3 Brief Overview of the Conceptual Research Model

To address the research question, a conceptual research model has been developed. The conceptual research model is presented in Figure 1.1. The model is based on prior research on social capital, organizational behavior, community and virtual collaboration. Three types of motivational factors are selected to study their effects in the

open source context. These factors are extrinsic incentive, which is reputation gaining, personal software needs, and learning purpose; intrinsic motivation, which is enjoyment; and relational social capital, which is identification and obligation. They are the central factors in the model, and have been studied in recent decades for traditional organizations, communities and groups. They are believed in this research to play an important role in open source software development to sustain the community and promote participative behaviors that are beneficial to the success of project. A member's identification with and obligation to the open source community refer to the strength of an individual's psychological attachment to the community (Dutton et al. 1994). Based on literatures in social capital, organizational behavior, community psychology and virtual collaboration, some major factors are included in the model as antecedents to the central factors. The factors are congruence between individual and project goals, shared values between the member and the community, trust (cognitive and affective trust), and perceived leader support. These factors are expected to affect the developer's enjoyment with the open source community, identification with and/or obligation to the open source community through the promotion of self-categorization, self-enhancement and social exchange. Among these antecedent factors, shared values, goal congruence, trust and perceived leader support are determinants to enjoyment; shared values, goal congruence, trust and perceived leader support are determinants to identification and obligation. The consequences of reputation, software needs, learning purpose, enjoyment, identification and obligation are the member's participative behaviors in the project. These behaviors are critical to the success of the project, since they enhance the effectiveness and efficiency of the process in open source software development.

1.4 Research Method

To test the model, data will be collected from open source software developers using surveys. Active ongoing projects on the major open source websites, Sourceforge.net, will be randomly selected as sample for the study. In order to increase the response rate, a web survey will be conducted. Survey questions are posted on a research website, so the respondents can directly answer the questions online. The measurements for the constructs in the research model are based on existing scales from prior literatures, with some wording changes or adaptations being made to allow the questions fit the open source context better. For the purpose of random sampling, open source projects of various type, size, age and location are selected, and then developers in the communities are chosen as subjects for surveys.

The collected data are analyzed using statistics methods such as structural equation modeling. The research model and hypotheses are tested based on the results of data analysis.

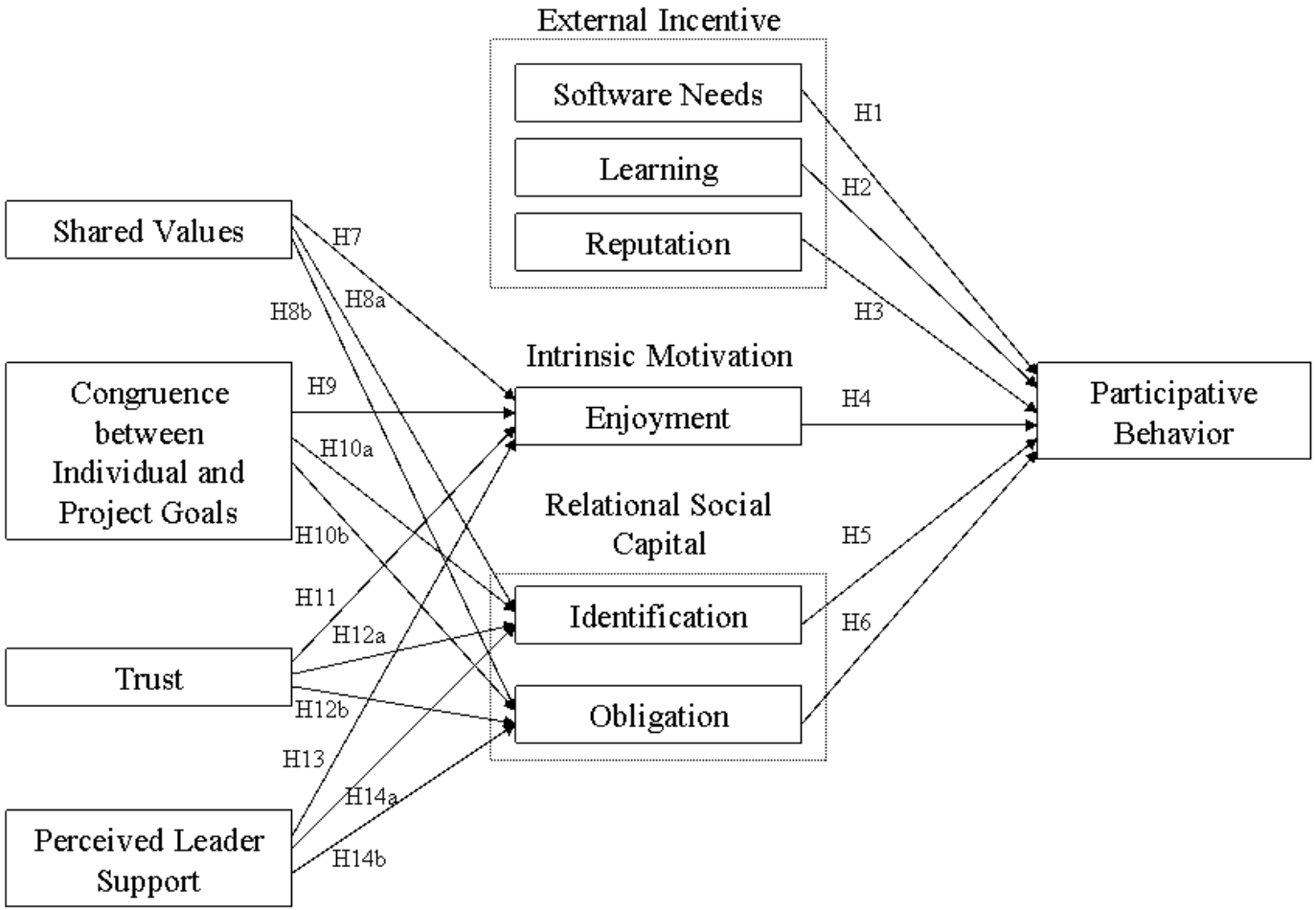

Figure 1.1 A Conceptual Model for Research

1.5 Expected Contribution

The results of this research are expected to contribute to open source software, virtual collaboration and organizational behavior.

1.5.1 Contribution to Open Source Software Research

Although it has been three decades since the emergence of open source software, research on open source software gained attention only in the past years with the increasing influence of open source software on the software industry and social life. Currently, in the field of information systems, research on open source software is mainly focused on the volunteers' motivation for open source participation. There has been little research to study the characteristics of open source community and their influence. Like other types of online communities, open source community is considered to be a social structure because of relationships developed among the members and between the members and the community. This research studies the role of social relational capital, including identification and obligation, in open source software development, it is expected to add to the open source software literature and have practical implications for the management of open source project.

1.5.2 Contribution to Virtual Collaboration Research

Research on virtual collaboration has been popular is recent years with the emergence and spread of online collaboration structures like virtual teams and virtual communities. Currently, research on virtual collaboration is mainly focused on the development and role of interpersonal trust on virtual collaboration performance.

Relational tie is likely to play a very important role in virtual environment, since direct monitoring or supervision is impossible in such context. However, there has been very little research on identification and obligation in virtual environment, it is still unclear how and why identification and obligation forms with virtual collectives (Powell et al. 2004). Open source community is a type of virtual collaboration, which is self-organized and loosely structured in nature. Study of the social capital in open source community is expected to contribute to the theory of virtual collaboration and practice of virtual environment management.

1.5.3 Contribution to Organizational Behavior Research

Open source community is regarded as a new organizational form for knowledge creation (Lee and Cole 2003). It has some special traits that are significantly different from traditional firm-based organizations. There has been no research to examine whether the theories and research results about organizational behaviors can be extended to the new organizational context. This research is expected to fill this gap by investigating the social identification and social exchange relationships and their effects in the open source communities based on some theories of organizational behaviors. Thus, this research is expected to contribute to organizational behavior research through theory extension.

1.6 Overview of the Following Chapters

The outline of the dissertation is organized as follows. Chapter Two presents the theoretical background for the study and a literature review of open source software,

organizational identification, and virtual community. It also provides a general view of the constructs in this research. Chapter Three focuses on the research model. On the basis of the literature review, the research model is developed and research hypotheses are then explained. Chapter Four focuses on the research method, how the sample is defined, how data are collected, how constructs in the research model are operationalized, and how surveys are designed. Chapter Five describes how measures are validated, how research hypotheses are tested, and results of data analysis. Chapter Six draws implications from the empirical data analysis, presents research limitations, and outlines future work that will follow this dissertation.

CHAPTER II

LITERATURE REVIEW

2.1 Overview

In this chapter, previous research on open source software is reviewed to show the deficiencies of both theories and empirical studies in open source software. Open source software is developed in a web-based virtual community by voluntary contributors; it does not have formal control mechanisms as traditional software development. Therefore, developers' motivations and participation are critical to the success of an open source software project. To get an in-depth understanding of open source software project success, the open source community should be studied as a social organization, and the social relationships within the community and their impact on developer's behavior and performance should be investigated. Previous research in the fields of social psychology, organizational behavior and information systems are reviewed to understand the role of social relationships in improving performance in different types of organizations.

2.2 Open Source Software Research

Prior studies of open source software are mostly focused on the structure of open source communities, incentives and motivation of open source software development participation, and some processes of open source software development.

2.2.1 Structure of Open Source Community

Open source software is regarded as a revolution in software development from proprietary or private-owned to free or public, it is also a great change in production organization from firm-based to community-based (Lee and Cole 2003). Many user-initiated open source software projects are conducted on the Internet. The major characteristics of open source software development are: (1) it is community-based and the membership is open; (2) worker incentives and motivations shift from those of employees to those of volunteers, and unlike in a firm setting, there isn't an authority relationship to regulate the behavior of community members; (3) members are organizationally and geographically dispersed, and (4) the knowledge-creation platform is based on a many-to-many computer mediated communication technology. These four characteristics make open source software a different organization structure from traditional software development. The most important advantage of open source is that the knowledge is public. It is freely accessible to all. Because commercial software vendors typically wish to sell the code they develop, they sharply restrict access to the source code of their software products. The consequence of this restriction is that only insiders have the information required to modify and improve that proprietary code. In sharp contrast, all are offered free access to the source code of open source software, which means that anyone with the proper programming skills and motivation can use and modify any open source software written by anyone. Today, an open source software development project is typically initiated by an individual or a small group with an idea for something interesting they themselves want for an intellectual or personal or business reason. The project initiators generally become administrators or maintainers who are

responsible for the project management. And developers are usually persons who have interests in the projects and voluntarily participate (von Hippel and Krogh 2003).

Open source software is based on virtual community which is an online social structure that gained popularity with the wide spread of the Internet. The open source community can be classified as a virtual community of practice because its main purpose is to gather geographically distributed people which share common interests to perform a task and reach a common goal. The basic structure of an open source community is showed in Figure 2.1 (Adapted from Crowston and Howison 2005).

Open source software takes virtual community as its organization structure. Members in a open source software community play different roles. In the Linux community, there is a two-tier structure with four categories of developers.

- The core is the project leader and maintainers, they are in charge of the project and maintain the versions.
- The periphery includes (1) the developers who write "PATCH" and send with email to contribute to the code, their tasks include creating patches, adding features, and fixing bugs. And (2) the bug reporters who report or fix bugs, their tasks include identifying bugs, characterizing bugs, and eliminating bugs. There are some overlap between the developers and bug reporters.

In some other open source software community participants play roles as core developer, code contributor, code repository administrator, reviewer, or end user. The development of software is conducted through collaboration between developers, and the maintenance as evolutionary redevelopment, reinvention and revitalization (Scacchi 2004). The core developers offer most of the contribution and perform most of the

development work (O'Reilly 1999; Koch 2004). End users and other members in the community report bugs and send suggestions of new features, which is important for the upgrade and evolution of the software (Holmstrom 2004; Zhao and Deek 2004). AlMarzouq et al. (2005) describes open source community as composed of core members which make majority of code contribution, co-developers which make bug reporting, feature requests, occasional code contributions and bug fixes, active users which make bug reports and feature requests, but no code contribution, and passive users or freeloaders which make no contribution at all. On sourceforge.net, each project has one or more administrators and some developers, the administrators are mostly developers themselves. Administrators and developers are the core of the project community, they develop the core part of software and maintain the software. Users are in the periphery of the project community, they might be pure end users who have interests in the software or developers in other projects. Users write "PATCH", report bugs, or request new features. They discuss and share information or experience through the public forums.

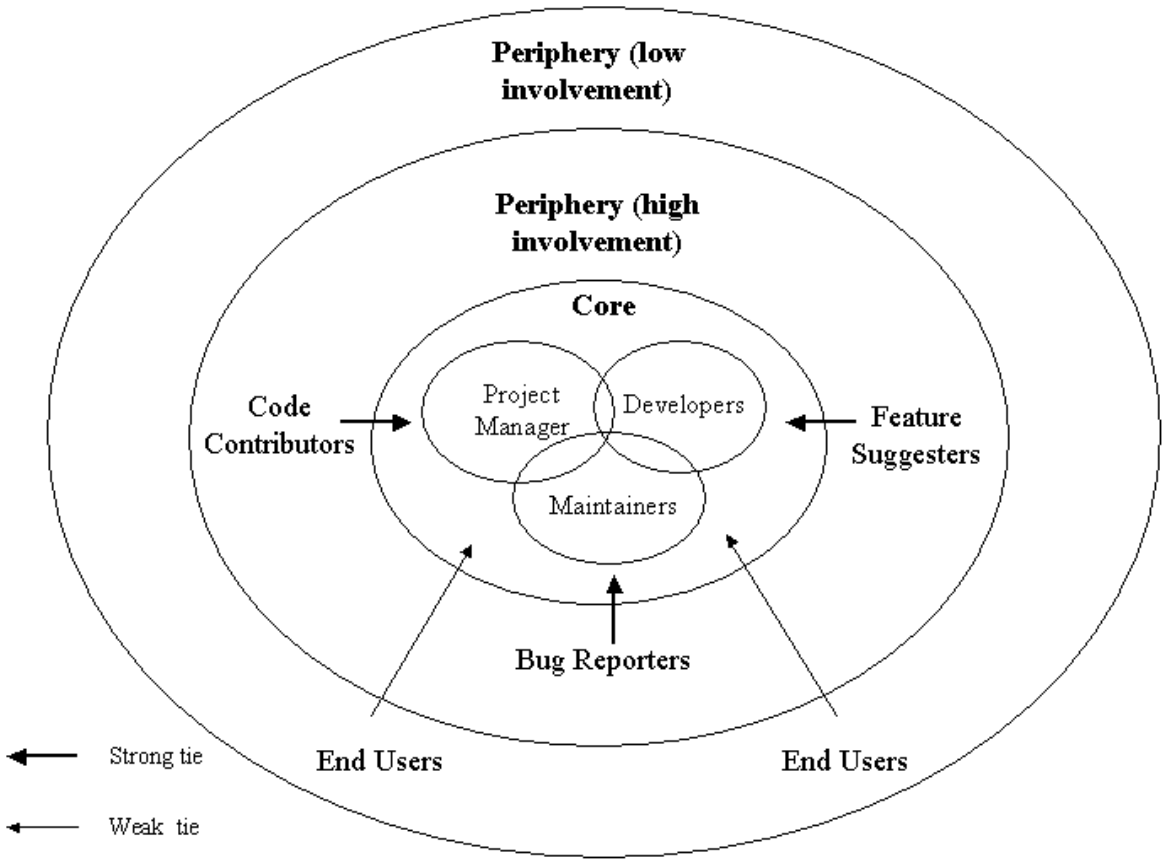

Figure 2.1 An Open Source Software Community Structure

- Ownership

Ownership is an important issue in open source projects. There are basically three ways to acquire ownership of an open source project: to found it; to have it handed over by the former owner; or to volunteer to take over a dying project where the former owner has lost interest (Ljungberg 2000). The owner of an open source project used to be leader of the development, practicing a benevolent dictatorship, as the project attracts more contributors, the owner becomes more of a coordinator or project leader.

- Ideology

Ideology is important to the cohesion and sustainability of an open source community. One dimension of the ideology is zealotry. The open source development may be viewed as a means to an end of producing free software of high quality (the view that open source is a good way to build software), or it may be viewed as an end in itself (the view that open source is a philosophy and way of life). Another dimension is the degree of hostility to commercial software. For anti-commercial person writing free software can be seen as a resistance movement against large software corporations, while a non-anticommercial person might think commercial software is OK and may co-exist with open source movements.

According to Stewart and Gosain (2005a), ideology refers to the key norms, beliefs and values in OSS community. They summarized the OSS norms, beliefs and values as follows:

OSS norms

1. No forking – there is a norm against forking a project, which refers to splitting the project into two or more projects developed separately.
2. Distribution – there is a norm against distributing code changes without going through the proper channels.
3. Named credit – there is a norm against removing someone's name from a project without that person's consent.

OSS beliefs

1. Code quality – open source development methods produce better code than closed source.

2. Freedom – outcomes are better when information, especially code, is freely available.
3. Bug fixing – the more people there are working on the code, the more quickly bugs will be found and fixed.
4. Practicality – practical work is more useful than theoretical discussion.
5. Status attainment – status is achieved through community recognition.

OSS values

1. Sharing – sharing information is important.
2. Helping – aiding others is important.
3. Technical knowledge – technical knowledge is highly valued.
4. Learning – there is a value on learning for its own sake.
5. Cooperation – voluntary cooperation is important.
6. Reputation – reputation gained by participating in open source projects is valuable.

It has also been empirically showed that members' adherence to OSS ideology would affect the effectiveness of the projects.

2.2.2 Open Source Software Development Process

The open source software process is quite different from the traditional process for proprietary software. An open source project is often started from a single person's 'itch' or desire, and it evolves in number of developers and software features to be an increasingly more complicated organization (Thomas and Hunt 2004). The most generic form of the traditional software development life cycle (SDLC) includes the stages of planning, analysis, design and implementation. However, in the open source software

development life cycle, the planning, analysis and design phases are largely conducted by the initial project founder, and are not part of the general development life cycle (Feller and Fitzgerald 2002). The open source software development life cycle is located primarily within the implementation phase of the traditional SDLC, and follows a spiral model. Jorgensen (2001) identified the main phases in the open source software development life cycle as code, review, pre-commit test, development release, parallel debugging and production release.

Scacchi (2004) summarized open source development processes as five types, which occur concurrently rather than strictly ordered as in traditional life-cycle model.

1. Requirements analysis and specification – open source requirements take the form of threaded messages or discussions on web sites that are available for open review, elaboration, refutation or refinement. They don't result from explicitly stated needs of user representatives or product marketing strategies.
2. Coordinated version control, system build, and staged incremental release-review – the Concurrent Versions System (CVS) serves as both a centralized mechanism for coordinating OSS development and a venue for mediating control over which software enhancements, extensions, or upgrades will be checked in to the archive. The activity is recurrent. Each project team or CVS administrator must decide what can be checked in and who can and cannot check in new modified source code content. Some projects, like Apache, makes the policies visible through voting scheme (Fielding 1999). But in most other projects the process is informal, implicit and subject to negotiation.

3. Maintenance as evolutionary redevelopment, reinvention and revitalization – the traditional label of maintenance doesn't fit what is occurring in OSS community very well. It might be better to characterize the overall evolutionary dynamic of OSS as reinvention, which is continually emerging adaptation, learning, and improvement in OSS functionality and quality. OSS systems seem to evolve through minor improvements or mutations that are expressed, recombined, and redistributed across many releases with short life cycles. OSS systems co-evolve with their development communities; one's evolution depends on the other's.
4. Project management and career development – OSS development teams can take the organizational form of interlinked layered meritocracies operating as a dynamically organized but loosely coupled virtual enterprise. A layered meritocracy is a hierarchical organizational form that centralizes and concentrates certain kinds of authority, trust, and respect for experience and accomplishment within the team. Project participants higher up in the meritocracy have greater perceived authority than those lower down (Glass 2003). The participants in an open source community are usually specialized. When a new member enter, he would experience a process of socialization and specialization (Krogh et al. 2003).
5. Software technology transfer and licensing – OSS technology transfer is not an engineering process, it's instead a sociopolitical process that entails the development of constructive social relationships; informally negotiated social agreements. Community building and sustained participation are essential, recurring activities that let OSS persist without central planning and management.

2.2.3 Open Source Project Organization and Management

Krishnamurthy (2003) analyzes the advantages and disadvantages of OSS. For closed source or proprietary software, there is strict separation between producer and user; but for OSS there is author-user interaction and user-user interaction in the larger community. OSS is free which leads to quick diffusion; it has larger developer and tester base; the peer review equals reliability; the use is flexible; and it has customer support from a community. On the other hand, OSS may incur version proliferation due to different evolution paths, and it may appeal only to high-end users. Paulson (2004) empirically compares open and closed source software, and found that open source development fosters faster system growth and more creativity. Open source projects generally have more simplicity, they generally have fewer defects because defects are found and fixed more quickly, and they are more modular than closed source projects. Payne (2002) analyzes the security issue of open source software. It compares three different operating systems (closed vs. open source) in security features to show whether open source software has enough security compared with proprietary closed software. Stamelos et al. (2002) empirically test the code quality of open source software, and indicates that the average component size of an application is negatively related to user satisfaction for the application.

Coordination, control and quality assurance mechanism are important in traditional software engineering. In open source projects, they take some different forms.

The leader of the project has the right to make decisions and has the obligation to credit contributors fairly. When a project grows it is common that it will be split into subsystems with subsystem-owners, and there are two kinds of contributors: ordinary

contributors and co-developers. Development, design and planning are totally decided on by the leader eventually in cooperation with the co-developers, and with suggestions from ordinary contributors (Koch and Schneider 2002, Bonaccorsi and Rossi 2003). The project leader or manager plays an important role in managing conflicts in the open source community (Joode 2004).

Since people volunteer by interest and for free, conventional controlling might be ineffective or even have a negative effect. Gallivan (2001) studied the role of control and trust in the open source community, and found that the balance between trust and control is important to the successful coordination of open source projects. Sagers et al. (2004) examine the network governance in open source community. Network structure is a governance form based on social interactions and informal controls, and open source project success is dependent upon the ability to coordinate and safeguard interactions, which is enhanced by social controls. Lee and Cole (2003) study the open source project as a community-based model of knowledge creation. They examine the coordination, quality control and authority structure in the Linux community to see how the community mechanism works for collaborative generation of high quality source code.

Lee and Cole (2003) found that the openness and peer review mechanism makes open source software often have higher quality than closed source software, because bugs can be found, reported and fixed more efficiently. Zhao and Elbaum (2003) explore how software quality assurance is performed under the open source model, and its practical advantages. They found that the open source community mechanism provides a better way for quality assurance than the traditional way of software development.

Huntley (2003) studies organizational learning effects in open-source projects. Through observation of the debugging process in Apache and Mozilla projects they found the learning curve effects of project-specific experience on bug cycle times, and some projects derive more benefits from the positive learning effects than others.

Because of the numerous advantages of open source development, it would appear advantageous for the for-profit organizations to build new business models which combine the advantages of both open source and traditional development organizations. Sharma et al. (2002) proposed a framework for creating hybrid-open source software communities within an organization. West (2003) proposed strategies for melding the proprietary and open source platform which combine the advantages of open source software while retaining control and differentiation. Franke and von Hippel (2003) recommend the open source development as a means to satisfy heterogeneous user needs since it more effectively and broadly involves the users in the innovation process than traditional product development.

2.2.4 Incentives and Motivation for Open Source Software Contribution

Why do people participate in open source projects? Markus et al. (2000) examine the underlying mechanism which makes an open source virtual community work. The motivation for contribution to open source project includes social and economic benefits. The social benefits include altruism and gift giving, reputation, and ideology. Altruism and reciprocity refers to that people enjoy the sense of "helping others out" and "giving something back"; participation in open source projects is one way that software workers can develop a name for themselves or enhance their reputations, and gaining or

enhancing reputation through participation in open source projects can lead to such tangible rewards as employment opportunities or access to venture capital. The ideology that giving software away is the right thing also motivates participation in open source projects. Hars and Ou (2002) survey developers in open source projects to understand their motivation to participate. The motivations fall into two broad categories: internal factors (intrinsic motivation, altruism, community identity) and external rewards (expected future returns, personal needs). Intrinsic motivation refers to developers being motivated by feelings of competence, satisfaction, and fulfillment that arise from writing programs. Altruism is a variant of intrinsic motivation in which one seeks to increase the welfare of others; community identity occurs when developers identify themselves as members of the open source community. For external rewards, open source developers may view participation as an investment from which they will obtain future returns. Open source software provides many opportunities for selling related products and service. Developers may also expand their skills base through participation in open source. Developers may regard working for open source projects as an effective way to demonstrate their capabilities and skills, and their achievements in open source projects can be used to reinforce their claims to programming competence. Personal needs also play a role in motivation. Open source software is often driven by developers' personal need for specific functionalities. Hann et al. (2002) study economic incentives for participation in open source projects, and find that employers do reward high rank in open source projects, but accumulation of open source experience would not lead to wage increase. Von Hippel and Krogh (2003) regard software development as an innovation process, and use theory related to incentives for innovation to explain OSS participation.

They propose a "private-collective" innovation model and find that OSS development is a model that "contains elements of both the private investment and the collective action models and can offer society the 'best of both worlds' under many conditions". Hertel et al. (2003) consider OSS project as a social movement so the motivations for developers participating OSS is similar to those participating other social movements like civil rights movement. Von Hippel (2001) studies open source participation from the perspective of user innovation, regarding the open source community as a user innovation community. A user innovation community exists if there are three favoring conditions: incentives for users to innovate, incentives for users to reveal innovation freely, and innovation diffusion by users. For open source software these three conditions exist, so an open source community works as a user innovation community. Krogh (2003) indicates that many programmers participate in open source projects to learn to develop complex software, and many contributors have important pragmatic motives to improve their own software. Hertel et al. (2003) surveyed the contributors to the Linux kernel and found that the participants' level of engagement is determined by their identification as a Linux developer. These Linux developers had pragmatic motives to improve their own software. The team goals, perceived indispensability and self-efficacy also affect their participation. Hann et al. (2004) surveyed three projects under the Apache Software Foundation and found that the major motivations for open source participation are use value, career concern, reputation, normative motivation and recreation. Although most research focused on the incentives and motivation for the participation in the major tasks of software development, Lakhani and von Hippel (200) studied the motivation for some

"mundane but necessary" tasks like helping users in open source community and found that the major motivation for such behavior is to reciprocate the learning benefits.

To summarize, the motivations for open source projects participation include economic incentives, job prospects, enjoyment, learning purposes, cooperation needs, open source ideology, and personal needs. The importance of different motivations may vary by project or individual.

Table 2.1 Incentives and Motivations for Open Source Software Contribution

Source	Intrinsic Motivations	External Factors
Markus et al. (2000)	Altruism, gift giving, ideology	Reputation, employment opportunity
Hars and Ou (2002)	Altruism, community identification	Future rewards, human capital, self-marketing, peer recognition, personal needs
Hann et al. (2002)		Economic incentives
Hpppek an d Krogh (2003)	Innovation incentives	
Hertel et al. (2003)	Social movement motivations	
Von Hippel (2001)	User innovation	
Krogh (2003)		Learning, personal software needs
Hertel et al. (2003)	Identification, team goals, self-efficacy	Personal software needs
Hann et al. (2004)	Normative, recreation	Personal software use, career concern, reputation

2.2.5 Social Issues in Open Source Software Development

Stewart and Gosain (2001) find that the open source ideology and trust among team members have significant impact on group effectiveness. Trust is influenced by the shared ideology and communication among team members. Stewart and Gosain (2005b) also find that the role of trust and ideology in determining performance varies across stages. Gallivan (2001) investigates the balance between trust and control, and its effect on open source software development effectiveness. Koch and Schneider (2002) retrieve data from the CVS repository of an open source project to estimate the total effort expended on the project. The results show the existence of a relatively small "inner circle" of programmers responsible for most of the output. A typical successful project has a steady increase in size, the number of active programmers has a staggering rise during a prolonged time period, but relatively stable for a short time period. Bergquist and ljungberg (2001) analyze open source development model based on theories of gift economies. The gift economy in an open source community creates openness, and organizes relationships between people in a certain way. Open source software relies on gift giving as a way of getting new ideas and prototypes out into circulation. The giver gets power from giving away. Zeitlyn (2003) also studied the role of gift giving in open source participation. Oh and Jeon (2004) studied the membership dynamics and network stability from the ising perspective, and found the influence of member interconnection on the stability of open source community. O'Mahony (2003) investigates the tactics by open source projects to protect their work from intellectual property rights perspective, and states that the intellectual property for open source software is publicly and freely

available, yet governable. Vemuri and Bertone (2004) analyze the chance for the open source movement survival from litigious perspectives.

2.2.6 Survival of Open Source Projects

Crowston, Annabi and Howison (2003) identify a range of measures that can be used to assess the success of open source software projects. The measures relate to user (satisfaction, involvement), project (meets requirements, code quality, portability, availability), process (activity, adherence to process, bug fixing, time, age), developers (involvement, varied developers, satisfaction, enjoyment), use (competition, number of users, downloads), recognition (referral, attention and recognition, spin offs), and influence. Smith and Sidorova (2003) examine survival of open source projects from a population ecology perspective. Project reliability, size, age and niche focus are related to the survival of open source projects. Stewart and Ammeter (2002) examine what differentiates successful from unsuccessful open source software projects. They study the influence of organizational sponsorship, target audience, license choice, and development status on the extent to which open source software projects attract user attention and developer activity. Stewart et al. (2005) also studied the influence of licensing and organizational sponsorship on the popularity and viability of open source software projects, and concluded that organizational sponsorship has positive but licensing restrictedness has negative effect on the success of open source software projects.

The prior studies have investigated open source software from multiple perspectives, including organization, psychology, economics, and social sciences. These

studies help us understand how open source software is developed and how the open source community is organized and structured. However, currently the research on open source software leaves many questions to be answered. For example:

- Most research has focused on understanding the structure and organization of open source software development, but there have been few studies about the success factors of open source software.
- Most research is focused on understanding the motivations or incentives for open source participation at general level, but there have been few studies on understanding participant's behavior in the open source community.
- For research about motivations for open source participation, few of them are theory-based. In addition, there is no study to integrate the influencing factors to see how they perform impact together and complement each other in motivating open source developers' voluntary participative behaviors.
- There has been very little research about the influence of community characteristics on the participants' behaviors, which are determinants to the successful outcome of an open source project.
- There has been little research to offer guidance for project leaders on how to manage the open source software development.

According to Hoegl and Gemuenden (2001), the most critical factors to success of innovative projects are communication, coordination, balance of member contribution, mutual support, effort, and team cohesion. Open source software development is conducted in the organization of virtual community which is self-organized, loosely structured without formal control mechanisms or legal contract between the voluntary

participants and the developing community. Therefore, how to promote the volunteers' participative actions, and how to encourage the developers to make more effort for the achievement of the common goal, are critical to the final outcome of the open source project. More studies are badly needed on these aspects of open source software development.

In order to better understand the motivational factors in open source context, it is necessary to review the related research in virtual community studies to know what factors are demonstrated to be important in determining participation in online communities.

2.3 Virtual Community Research

Open source software development takes virtual community as its organizational form. It is reasonable to believe that the attributes of virtual community have impacts on participants' behaviors and may affect the final outcomes of software development.

According to Howard (1993), virtual communities are "social aggregations that emerge from the Internet when enough people carry on public discussions long enough, with sufficient human feeling to form webs of personal relationships in cyberspace". The common aspects from the different definitions of virtual community include: 1) Cyberspace – virtual community should be on the net, use computer-mediated spaces, or cyberspace; 2) usage of computer-based information technology to support the activities in virtual community; 3) communication and interaction – content or topics of virtual community are driven by the participants (Lee et al. 2003). According to Whittaker, Issacs, and O'Day (1997), some of the attributes of an online community might be: 1) a

shared goal or interest that provides the reason for being a part of the community; 2) intense interactions and strong emotional ties; 3) shared activities between community members; 4) access to shared resource; 5) support between community members; 6) social conventions, language or protocols. Virtual communities can be divided into some different types based on their purpose. Hagel and Armstrong (1997) classified virtual communities into community of interest, community of relationship, community of transaction, and community of fantasy. Carver (1999) classified virtual communities into community of interest, community of relationship, community of entertainment and community of commerce.

In short, virtual communities are Internet applications where people can find and then electronically "talk" to others with similar interests. Currently research is focused on fundamental understanding of virtual community. Virtual communities are transforming the society through integration of production systems beyond national borders, cultural and value exchange, and redefinition of personal relationships (Romm, Pliskin and Clarke 1997). Virtual community has been regarded as an online social structure, not merely a software application, because users participating establish identities and build relationships as in physical communities (Cummings et al. 2002; Blanchard and Markus 2004).

Among the research of virtual community, the motivations of virtual community activities are of great interests to many researchers. As in physical communities, participation in virtual communities is voluntary and self-motivated, and volunteers' participation is critical to the survival and success of a virtual community. Wasko and Faraj (2000) examines why people participate and share knowledge in three electronic

communities of practice. The survey results indicate that people participate primarily out of community interest, generalized reciprocity and pro-social behavior. There are also some other studies reveal the role of incentive mechanism, social identity and social exchange relationships in virtual community participation (Gu and Jarvenpaa 2003). Wasko et al. (2004) and Wasko et al. (2005) investigated virtual communities from social network perspective, and found that individual motivation (including external incentives like reputation and intrinsic motivation like enjoyment) and relational capital (identification and obligation) are the major factors which determine virtual community participation. Li et al. (2005) also found that enjoyment is important for participants' involvement in an online community. Ridings et al. (2002) studies the role of trust in virtual communities, and indicates that trust plays an important role for members to give and get information to and from each other. Butler (2001) studied the motivation of virtual community activities based on the rational cost-benefit aspects and analyzed the relationship between membership size and participants' continuance.

So based on prior studies on virtual community, we know that the major motivations for virtual community participation or contribution are external incentive (reputation gaining), intrinsic motivation (enjoyment) and relational factors (identification, obligation, commitment). These motivational factors are supposed to apply to open source communities, which are a specific type of virtual community.

Currently, studies on the motivational factors of open source software development are mainly focused on the external and intrinsic motivations, which suggest that volunteers involve in open source software development for the purpose of gaining

reputation for job prospect and for enjoyment. These factors are not under the control of open source project management. Online structure is a social structure because relationships can be developed among persons (Cummings et al. 2002; Kraut et al. 1999). Social relationship factors have been studied for organization, physical community and other social structures, and they are found to have motivational effects on individuals. There are some theories in social psychology and organizational behavior about the motivational effects of social relationships, including social capital theory, social identity theory, social exchange theory, theory of organizational identification, psychological contract theory, and theory of citizenship behavior.

The social relationships in online structures like global virtual teams and virtual communities have been studied and it is demonstrated that interpersonal relationships can be developed even though there is no face-to-face interaction within such online organization (Jarvenpaa et al. 1998; Jarvenpaa and Leider 1999; Blanchard and Markus 2004). There has been few research to investigate open source communities from social perspectives, and the social relationships and their effects on individual behaviors have not been well understood.

In order to understand the motivational effects of social factors, it is necessary to have a review of related theories and studies from social psychology and management.

2.4 Relational Social Capital

Social capital is typically defined as "resources embedded in a social structure that are assessed and/or mobilized in purposive action" (Lin 2001, p.29). Social capital concepts have been offered as explanations for a variety of pro-social behaviors,

including collective action, community involvement, and differential social achievements that the concept of individual-based capital (such as human or financial capital) is unable to explain (Coleman 1990). The key difference between social capital and other forms of capital is that social capital is embedded in the social realm. While other forms of capital are based on assets or individuals, social capital resides in the fabric of relationships between individuals and in individuals' connections with their communities (Putnam 1995).

Nahapiet and Ghoshal (1998) proposed the theoretical model for social capital. Based on this model, there are three forms of social capital (cognitive, structural, and relational). Cognitive capital refers to those resources that make possible shared interpretations and meanings within a collective. Engaging in a meaningful exchange of knowledge requires at least some level of shared understanding between parties, such as a shared language and vocabulary. Structural capital refers to the connections between individuals, or the structural links created through the social interactions between individuals in a network. The density and strength of the networks are important for collective action to achieve. Relational capital refers to the affective nature of the relationships within a collective. Relational capital exists when members have a strong identification with the collective (Lewicki and Bunker 1996), trust others within the collective (Putnam 1995), perceive an obligation to participate in the collective (Coleman 1990), and recognize and abide by its cooperative norms (Putnam 1995).

Relational social capital has been demonstrated to be important for knowledge exchange and creation in collective (Nahapiet and Ghoshal 1998). Among the four dimensions of relational capital, identification and obligation are considered to be the

relational ties or psychological bonds between an individual and the collective. Identification is based on the aspects of social identity, and obligation is the result and basis for social exchange relationship. Prior studies showed that both identification and obligation are important for an individual's loyalty and pro-social participative behaviors in physical organizations and online social structures (Wiesenfeld et al. 1999; Turnley et al. 2003; Wasko and Faraj 2005).

In the research about open source software development, there has been very few studies which investigate the role of relational capital in the open source community. Based on the understanding of interactions in online community, it is reasonable to believe that identification and obligation exist and play a very important role in promoting voluntary participants' behaviors. To get an in-depth understanding of the social relationship factors and their effects on human behaviors, the research on social identification, social exchange and citizenship behaviors in organizational context are reviewed as follows.

2.5 Social Identification Research

According to social identity theory, the self-concept is comprised of a personal identity, encompassing idiosyncratic characteristics such as abilities and interests, and a social identity, encompassing salient group classifications (Tajfel and Turner 1985). Individuals tend to classify themselves and others into various social groups, such as organizational membership, gender, and age cohort. Classification enables individuals to order the social environment and locate themselves and others within it. The theory maintains that individuals define a class according to the prototypical characteristics

ascribed to or abstracted from the members (Turner 1985). Social identification is the perception of belongingness to a group classification. The individual perceives him or herself as an actual or symbolic member of the group. Through social identification, he or she perceives him or herself as psychologically intertwined with the fate of the group, as sharing a common destiny and experiencing its successes and failures (Tolman 1943). Identification allows the individual to vicariously partake in accomplishments beyond his or her powers (Katz and Kahn 1978) and can render personally harmful activities worthwhile insofar as they aid the larger self (Staw 1984).

Social identification takes specific forms and is studied for both formal and informal organizations. Organizational identification is a specific form of social identification where the individual defines him or herself in terms of their membership in a particular organization. So it represents the social and psychological tie binding employees and the organization. Research on organizational identification suggests that strength of identification determines some critical beliefs and behaviors, including employees' feeling of interpersonal trust, goal-setting processes, internationalization of organizational norms and practices, desire to remain with the organization, and willingness to cooperate with others (Dutton et al. 1994; Kramer 1993). Organizational identification can facilitate coordination by promoting convergent expectations (Kogut and Zander 1996), motivate members to coordinate their efforts to achieve organizational goals (Kramer and Brewer 1984, 1986). Research suggests that members who identify strongly with the organization are more likely to accept organizational goals as their own personal goals; attend to super-ordinate goals, and be loyal and obedient (Dutton et al. 1994). Organizational identification is expected to correlate with work effort, willingness

to perform extrarole behaviors, and task performance. With the emergence and development of virtual organizations, organizational identification has been studied for employees in virtual organizations because there is no direct monitoring and supervision in the virtual environment and identification is considered to be more critical for the performance of virtual workers (Wiesenfeld et al. 1999; 2001).

Identification in an informal organization like a community has also been studied for its motivational effects on member's participative behavior and its relationship to sustainability of community. Community researchers have studied sense of community for many years since 1960s, because they think it is the affective bonds that differentiate communities from place-based neighborhoods. Sense of community has been found to increase satisfaction and organizational citizenship behavior in organizations (Burroughs and Eby 1998). In physical communities, the sense of community leads to commitment and is associated with involvement in community activities (McMillan and Chavis 1986). Sense of community is regarded as a feeling of belonging and attachment, which enhances some social processes and behaviors, such as providing support, developing and maintaining norms, and social control. Members with different degrees of sense of community vary in their level of participation in the community. Blanchard and Markus (2004) proposed the concept of sense of virtual community, and indicated that the sense of virtual community is a major factor that differentiates virtual community from just virtual settlement. Moreover, such type of online community identification would affect the member's prosocial behavior and participation in the community. Therefore, social identification plays an important role in both formal and informal organizations to motivate members' efforts which are beneficial to the organization.

2.6 Social Exchange Research

Social exchange theory provides a general approach for understanding the mutuality and reciprocity which affects member activities in an organization. In contrast to relationships based purely on economic exchange, social exchange relationships involve obligations that can not be specified ahead of time and requires the parties to trust one another (Blau 1964). This psychological contract is based on the exchange relationships between employee and organization. It is the employee's perception of the reciprocal obligations existing with their employer. As such, the employee has beliefs regarding the organization's obligation to them as well as their own obligations to the organization (Rousseau 1989). Prior research suggests that psychological contracts help to define the terms of the social exchange relationship that exists between employees and their organizations (Robinson &Morrison 1995; Shore & Barksdale 1998). These relationships are made up of the voluntary actions that each party engages in with the belief that the other party will reciprocate these behaviors in one way or another (Homans 1961).

Psychological contracts play an important role in the maintenance of the relationship between employee and organization. The motivational effects of psychological contracts have been studied, and it is found that psychological contract fulfillment has positive impact on the employee's in-role and extra-role behaviors (Turnley et al. 2003; Coyle-Shapiro 2002), while psychological contract unfulfillment has negative impact on the employee's performance level and commitment to the organization (Robinson and Morrison 1995).

Psychological contract takes the form of transactional and relational contracts. Transactional contracts are short-term, and economic or materialistic focused; relational contracts are long-term, broad, and include terms for loyalty (Rousseau and McLean Parks 1993). The contents of psychological contracts vary with persons and organizations, and they change dynamically. The contents of psychological contracts range from materialistic factors like payment to more abstract factors like emotional support.

Social exchange relationships also plays an important motivational role in communities. They are self-organized and informally structured compared with formal organizations like business companies. The exchange relationships motivate participation and help to sustain the communities, which are physical or virtual (Wasko and Faraj 2000; Blanchard and Markus 2004). Exchange relationships have been demonstrated to be important in nonprofit voluntary organizations in which the relationships between members and organizations are not as formally set as those between employees and employers. The exchange relationships motivate and sustain the volunteers' contribution (Farmer and Fedor 1999).

To summarize, social exchange relationships have great impact on the activities of members in various types of organizations. Psychological contract is the major form of exchange relationships between employer and its employees. Similar exchanges also exist in other types of organizations, which affect member's behavior.

2.7 Citizenship Behavior Research

Citizenship behavior is defined as individual behavior that is discretionary, not directly or explicitly recognized by the formal reward system, and that in the aggregate

promotes the effective functioning of the organization (Organ 1988). Citizenship behavior is not an enforceable requirement, but a matter of personal choice. Citizenship behaviors can be summarized into seven types (Podsakoff et al. 2000):

1. Helping behavior, which involves voluntarily helping others with, or preventing the occurrence of, work related problems;
2. Sportsmanship, is to tolerate the inevitable inconveniences without complaining, and to sacrifice one's personal interest for the good of the work group;
3. Organizational loyalty, entails promoting the organization to outsiders, protecting and defending it against external threats, and remaining committed to it even under adverse conditions;
4. Organizational compliance, is internalization and acceptance of the organization's rules, regulations and procedures;
5. Individual initiative, includes voluntary acts of creativity and innovation to improve one's task or the organization's performance, persisting with extra enthusiasm and effort to accomplish one's job, volunteering to take on extra responsibilities;
6. Civic virtue, is to participate actively in the organization's governance, to monitor its environment for threats and opportunities, and to look out for its best interests, even at great personal costs;
7. Self-development, is voluntary behaviors employees engage in to improve their knowledge, skills and ability.

These behaviors are all spontaneous, and beneficial to the organizational well-being.

Citizenship behaviors are related to social identification and social exchange in organizations. Both organizational identification and psychological contract are determinants of citizenship behaviors (Dutton et al. 1994; Turnley et al. 2003). Thus, citizenship behaviors are consequences of the social relationship between member and the organization. Citizenship behaviors have been found to have significant impacts on organizational performance. They are even more important for voluntary or community-based organizations since the performance and survival of such organizations are more dependent on volunteers' participative activities and voluntary contribution.

2.8 Research on IT Project Management

Open source software development can also be studied from the perspectives of project management since the development is organized in the form similar to project teams. Project management has been studied for a long time. Human resource management is an important part of project management, and it is related to the motivation of project participants to work for a project. There are some theories on human resources management, the most famous include Maslow's hierarchy of needs and Herzberg's motivational and hygiene factors. Maslow's hierarchy of needs indicates that people's behaviors are guided by a sequence of needs, including physiological, safety, social, esteem and self-actualization (Maslow 1971). Based on this theory, open source participation is mainly motivated by needs for social, esteem and self-actualization. Herzberg (1993) distinguished motivational and hygiene factors in work motivation. Motivational factors, including achievement, recognition, the work itself, responsibility, advancement, and growth, produce job satisfaction and motivate employees' work;

Hygiene factors, including larger salaries, more supervision, and a more attractive work environment, cause dissatisfaction if not present, but do not motivate workers to do more. In the context of open source software development, the motivational factors like achievement, recognition, work enjoyment, responsibility, advance and personal growth, are supposed to have great impact on a voluntary developer's engagement and involvement in the project.

Douglas McGregor popularized the human relations approach to management in the 1960s. McGregor's Theory X and Theory Y also reveal work motivations. Theory X assumes workers dislike and avoid work, so managers must use coercion, threats, and various control schemes to get workers to meet objectives; Theory Y assumes individuals consider work as natural as play or rest and enjoy the satisfaction of esteem and self-actualization needs (McGregor 2005). Open source participation is voluntary, and people participate in open source projects for the purpose of fun, professional growth, esteem and self-actualization, so it is better explained by Theory Y. In 1981, William Ouchi proposed Theory Z based on the Japanese approach to motivating workers, emphasizing trust, quality, collective decision making, and cultural values (Ouchi 1993).

The prior research on project management provides some insight on open source project management. In the context of open source software development, voluntary developers' participation and contribution can be promoted through recognition, sense of achievement, chance of learning and growth, work enjoyment, good interpersonal relationships, and cultural values.

Based on the previous research about virtual community, social relationships and project management, it is reasonable to believe that the incentives, intrinsic motivations and social relationships between the participants and the community together play an important role in promoting the activities and performance in an open source community, so they are critical to the success of an open source software development.

CHAPTER III

MODEL DEVELOPMENT AND RESEARCH HYPOTHESES

3.1 Overview

Volunteering participation is critical to the survival and success of voluntary organizations. Open source software development takes online virtual community as its organization form, and the developers are volunteers (Lee and Cole 2003). In this chapter, the research model is developed to study the motivational factors in open source communities, and their effect on developers' efforts and inputs in the software development process. The research model is based on prior studies of community activities, social capital theory, organizational identification theory and psychological contract theory, which define social identification, obligation and social exchange relationships in the organizational context. The constructs in the model are selected from previous research and fit into the context of open source software development. Figure 3.1 shows the research model.

3.2 Outcomes of the Model

Virtual community is often characterized by voluntary participation since there is no legal or contractual relationship binding the member to the community for contribution. Krogh et al. (2003) categorized open source participants based on the level of involvement into three types: joiner, newcomer and developer. In the open source software development context, developers' participation is critical to the viability of the community, and determines the final outcome of the software development (Markus et al.

2000). So, participative behavior is considered to be an important outcome variable. In an open source community the participation or involvement is more self-motivated than in formal organizations, and not complied to external forces.

Robey et al. (1989), in their study of group process and conflict in system development, conceptualize participation as "the extent to which members of an organization are engaged in activities related to system development". Prior studies in information systems found that participation generally improves group performance and has positively effects on the success of system development (Aladwani et al. 2000). According to Hoegl and Gemuenden (2001), members' effort, mutual support, cohesion and the coordination of the collaborative work are critical to the success of innovative projects. In the context of open source software development, the developers' voluntary participation is essential to the viability and final outcome since it is community-based. In an open source community, the members' participative behavior refers to their investment, effort and initiatives. There are some empirical studies to show that the level of voluntary participation, including code contribution, bug report, discussion forum posting, are positively related to open source software success (Long and Yuan 2005). Participation is studied as outcome variable because participative behaviors are essential to the final success of an open source software development, especially for the community-based environment in which the collective good is more dependent on the individual's voluntary contribution toward the achievement of the common goals. The relationship between participation and project success is furthered confirmed by the empirical study described in Chapter 6.

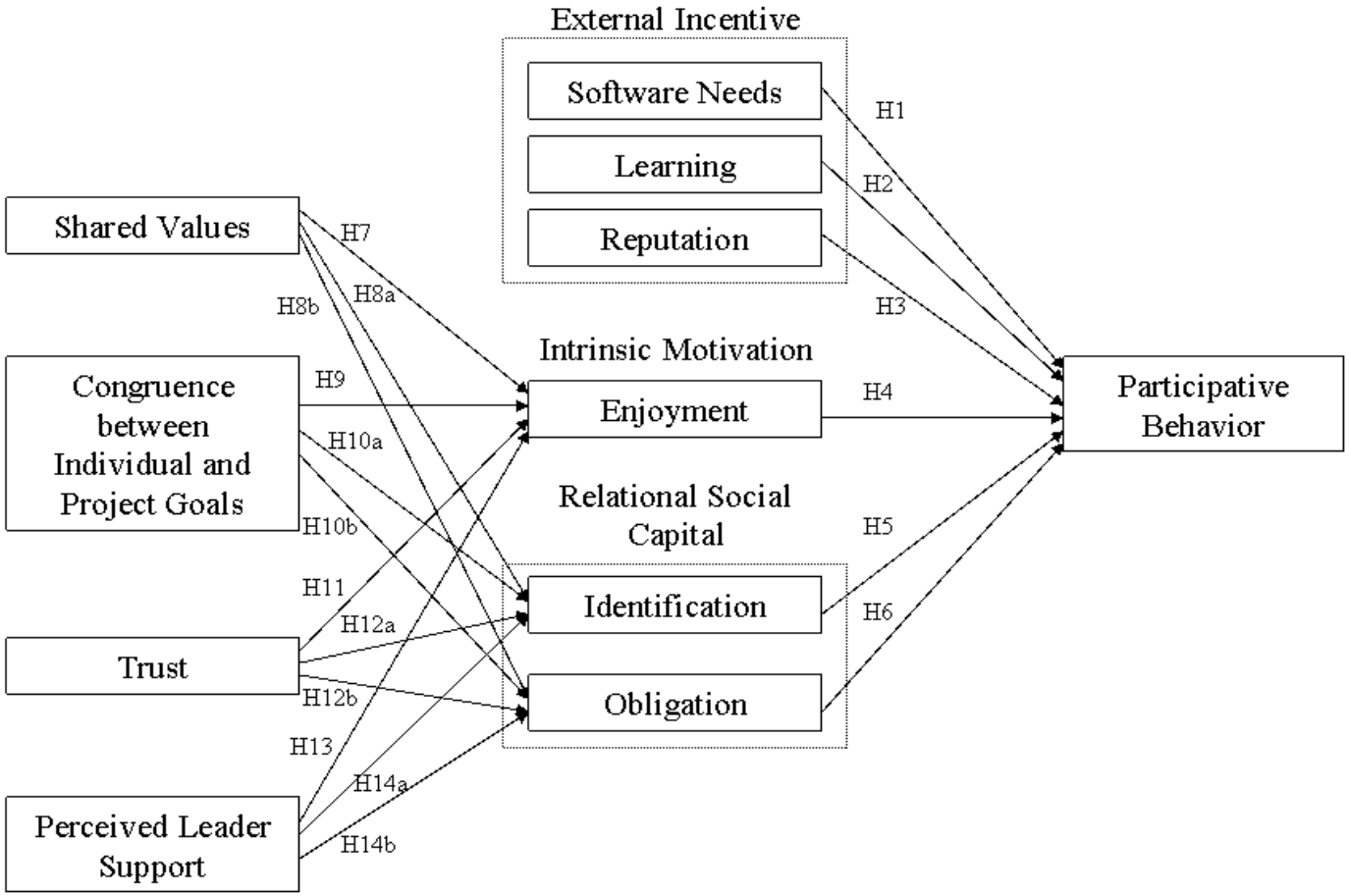

Figure 3.1 A Conceptual Model for Research

3.3 The antecedent factors in the model

The focus of the study is to investigate the motivational factors in the open source community and their effects on the outcomes. The central motivational factors in the model are external incentive factors, including reputation, software needs and learning; enjoyment, which represents intrinsic motivation; and social relational factors, which include identification with the open source community and obligation to the open source community. These factors are likely to have significant impact on voluntary developers' level of participation and involvement in software development. Reputation gaining and enjoyment are major individual motivations that explain voluntary participation or knowledge contribution in either physical or online communities (Wasko et al. 2005). Identification and obligation are two major aspects in social relational capital and serve as the relational ties between an individual and the collective (Nahapiet and Ghoshal 1998). Relational capitals are valuable assets possessed by an organization, and they are critical to the achievement of collective goals. According to some prior study about open source project development, personal software needs and learning desire are recognized as motivations for volunteers' participation, so they are also included in the model as extrinsic incentives.

The antecedent factors to enjoyment are shared values, congruence between individual and project goals, trust toward other members, and perceived leader support. The antecedent factors to identification are congruence between individual and project goals, shared values, trust (cognitive and affective) towards other members, and perceived leader support. The antecedent factors to obligation are congruence between

individual and project goals, shared values, trust towards other members, and perceived leader support. These factors and their relationships have been studied for communities and/or organizations, and they are selected to investigate their influences in the open source context.

3.4 Software needs and learning

Some survey or studies about open source software indicate that volunteers participate in an open source project because they have personal needs for the software being developed, and they want to learn software development skills through participation in open source project (e,g, Hars and Ou 2002). Personal software needs and leaning purpose are two external incentive factors in the context of open source software development, and they are expected to have impact on the developer's participative activities. The following hypotheses are offered:

Hypothesis 1: A member's personal software needs is positively associated with his/her participation in the community.

Hypothesis 2: A member's learning desire is positively associated with his/her participation in the community.

3.5 Reputation

Extrinsic incentives or rewards are important factors to motivate voluntary knowledge contribution activities (Bock et al. 2005; Kankanhalli et al. 2005). In communities, reputation is the major incentive for contribution. Reputation gaining is an important factor that motivates individuals to participate in community activities (Wasko

et al. 2001; Wasko et al. 2005). Gu and Jarvenpaa (2003) indicated that reputation mechanism like token may enhance individuals' knowledge contribution in online communities. Some other studies also demonstrated that reputation gaining is an important incentive for voluntary knowledge contribution activities (Kankanhalli et al. 2005). In open source context, reputation gained from project participation may help the developers' future job opportunities, and such expectation is important for an individual to take part in open source software development (Hars and Ou 2002). Reputation gaining is regarded as a major benefit of community participation. In open source context, the mechanism of copyleft guarantee that a voluntary developer's contribution can be recognized and he/she will gain reputation through participation. At the project or community level, an individual's perceived reputation gaining from being a member of a certain project or community is believed to have much impact on his intention to participate in the open source project. For this reason, the following hypothesis is offered:

Hypothesis 3: A member's perceived reputation gaining with the open source community is positively associated with his/her participation in the community.

3.6 Enjoyment

Reputation gaining is related to the rational calculation of benefits from community participation. It has been demonstrated that intrinsic joy or enjoyment also affects human behaviors greatly. Igbaria et al. (1996) found that enjoyment has significant impact on information systems usage due to the recreational basis of systems usage. As intrinsic psychological rewards, enjoyment represents an intrinsic motivation for human behaviors. Individuals who experience immediate pleasure or joy from an

activity and perceive the activity as inherently enjoyable, are likely to involve more extensively in the activity (Davis 1992). Wasko et al. (2001) and Wasko et al. (2005) investigated motivating factors for community involvement, and found that enjoyment is an important factor to motivate online community participation. Koh and Kim (2003) found that enjoyment is an important factor to motivate participants and critical to the success of an online community. Li et al. (2005) also found that enjoyment sustains individuals' community involvement though satisfaction of the need for interpersonal relationship building and the need for belongingness. Von Hippel and Krogh (2003) stated that open source participation is self-rewarded, because the developers feel that the participation itself is enjoyable. So, enjoyment is believed to be important to motivate a voluntary developer to participate into an open source community. The following hypothesis is offered:

Hypothesis 4: A member's perceived enjoyment with the open source community is positively associated with his/her participation in the community.

3.7 Identification with open source community

The organization form of virtual community is characterized by the lack of formal control. The effects of relational factors have been demonstrated to be more significant in the situation which lacks formal control or affiliation, such as strategic alliance (Nooteboom et al. 1997). Identification and obligation are the two important relational factors, and they are believed to be necessary in attracting and retaining the voluntary developers into a certain project.

Social identification is the social and psychological tie binding the person and social category. Social identification takes various forms in different contexts, and theory suggests that identification is caused by individuals categorizing themselves as part of an organization or the perception of "oneness" with an organization (Ashforth and Mael 1989; Dutton et al. 1994). Tajfel (1978) defined identification as the "cognition of membership of a group and the value and emotional significance attached to this membership". The cognitive component of identification reflects the perceived amount of interests an individual and an organization share. It conveys the extent to which an individual perceives him/herself as belonging to the group and as being a member of it. The affective component (feelings of pride in being part of the organization or feeling acknowledged in it) is important in the creation of a positive image of one's own organization, or achieving a "positive social identity". Research on identification suggests that strength of identification determines some critical beliefs and behaviors, including members' feeling of interpersonal trust, goal-setting processes, internalization of organizational norms and practices, desire to remain with the organization, and willingness to cooperate with others (Dutton et al. 1994; Kramer 1993).

Identification reflects the relationship between a member and the organization. As a new organization form, an open source community is composed of voluntary participants which gather together online to work for the development of software. Similar to organizational identification, here members' identification with the open source community is defined as a specific form of social identification where the individual defines him or herself in terms of their membership in a particular open source community. Research suggests that members who identify strongly with the organization

are more likely to accept organizational goals as their own personal goal, attend to super-ordinate goals, and be loyal and obedient (Dutton et al. 1994). Identification is more important in a virtual environment where direct supervision or monitoring is impossible or ineffective (Wiesenfeld et al. 1999; 2001). An open source community is characterized by its community-based organization in which developers join voluntarily, and leave freely. The lack of formal control mechanism and the innovative nature of open source software development implies that members' identification is a critical factor to the success of the project. It is the major factor that maintains the loosely–structured community into an effective collective which works for a common goal, and is important to facilitate coordination and motivate developers to align their personal goals with the fulfillment of the goals of the community.

The role of identification has been studied for both formal organizations and communities. Organizational identification has great impact on work effort and task performance (Wiesenfeld et al. 1999; 2001). Social integration, which is defined as people's involvement with community as well as their participation in the community's informal social life, plays a very important role in sustaining an active community (Gottlieb 1987). Community identification is critical to social integration and expected to correlate with active participation and contribution. It is also expected that identification can be formed in an online community environment since there are interpersonal relationships building among the participants (Blanchard and Markus 2004), and it may help sustain the knowledge contribution activities in online communities (Wasko et al. 2004; Wasko and Faraj 2005; Faraj and Wasko 2005).

It is reasonable to believe that identification exists and plays an important role in open source development communities. Similar to participants in other types of communities, open source participants join the community to satisfy their self-interests and personal needs, such as learning, reputation gaining and enjoyment. In the community context, participants may terminate their membership or reduce the level of actions when costs exceed benefits gained from community participation (Butler 2001), or they may switch to another community to become better "informed". However, identification raises concerns for the collective interests which merge with the individual's own interests (Johnson et al. 1999; O'Reilly and Chatman 1986). Under conditions of strong identification, the effects of certain costs and benefits may be nullified in the face of collective outcomes (Kankanhalli et al. 2005). To fulfill the collective goals of the open source community, which is to successfully develop the software, the degree to which the volunteers identify with their community is important. Identification is a major determinant of loyalty to the organization (Patchen 1970), and it has been empirically confirmed that identification plays an important role in sustaining membership and participation in various types of organizations (Thatcher et al. 2002).

Identification is related to the person's involvement in the collective actions. Identification with a collective conveys the sense of responsibility or obligation to perform in support of the collective goals (Coleman 1990). Organizational identification, or the strength of members' psychological link to the organization, has been associated with the degree to which employees are motivated to fulfill organizational needs and goals, their willingness to display organizational citizenship and other cooperative behaviors (Kramer 1993; Mael and Ashforth 1995). In the context of open source

community, where it is difficult to rely upon mechanisms such as direct supervision as a means of coordination and control, it may be left to the discretion of participants themselves to seek out and provide cooperative behaviors that further task performance and community goals. It is reasonable to expect that a member's identification with the open source community has influence on his/her level of participation and involvement in the project. In open source context, the developers' knowledge contribution behaviors are volitional and include performance of job duty, initiative (which is the contribution of useful ideas and suggestions), and helping behavior (which is to help other members for the solution of work-related problems). These voluntary activities are important to the successful development of an open source software.

In an open source community, there is specialization among the participants, and the project leaders have the authority to assign job tasks to developers, so each developer has some job duties (Krogh et al. 2003). It has been found that organizational identification motivates employees to voluntarily contribute more effort into performance than their job assignments for the good of the organization (Kramer 1993; Mael and Ashforth 1995). Therefore, it is reasonable to expect that identification may promote the developers' participation in the community.

Hypothesis 5: A member's identification with the open source community is positively associated with his/her participation in the community.

3.8 Obligation to open source community

Obligation represents a commitment or duty to undertake some activity. Obligations to the collective have been defined as a set of commitments, rights and duties

(Bourdieu 1977). Coleman (1990) views the creation of obligations as "a kind of insurance policy for which the premiums are paid in inexpensive currency and the benefits arrives as valuable currency". Obligations are important for binding persons together to work for a common goal and sustaining the long-term relationships, especially in the voluntary context without formal contractual relationships (Fairtlough 1994). Obligations have been demonstrated to be important and necessary for the success of cooperation or alliance like outsourcing even with the presence of a formal contract (Koh et al. 2004).

Obligations are generated from mutual exchange. A person who get benefits from others will feel obligated to reciprocate by returning (Hahapiet and Ghoshal 1998). So obligations are important to sustain the cooperation and interpersonal relationships. Obligations are critical to the cooperative activities among employees such as knowledge exchange in organizations (Leana and van Buren 1999). Obligations are also critical to the electronic networks of practice because they are generated from the generalized exchange between an individual and other members and serve as a major motivational factor for the knowledge contribution. Prior research finds that in an organizational electronic network, individuals posting valuable advice are motivated by a sense of obligation to the organization (Constant et al. 1996). In addition, findings from extra-organizational electronic networks suggest that individuals participate in networks due to a perceived moral obligation to pay back the network and the profession as a whole (Lakhani and von Hippel 2003; Wasko and Faraj 2000; Wasko and Teigland 2004).

In organizational context, obligations are studied as the sense of duties and responsibilities between employees and the organization. Obligations are reflected

through the psychological contract which contains the employee's sense of duties to the organization and expectations from the organization (Coyle-Shapiro 2000). Obligations are generated and maintained through met expectations and fulfillment of psychological contract (Turnley et al. 2003). An employee who feels obligated to the organization is more committed and loyal to the organization, and the absence of obligations may lead to employee turnover (Robinson and Morrison 1995). Obligations are even more important in the voluntary organizations or community-based cooperative environment since they are the critical psychological bond to hold the volunteers work together and sustain the alliance (Fairtlough 1994; Farmer and Fedor 1999).

In the context of open source community, obligations are expected to be generated because there is extensive exchange between an participant and the community, especially between the participant and the project leaders. An obligated participant is likely to be loyal to the community as obligated employee to his organization.

Obligations have been demonstrated to be an important relational factor that motivates citizenship behaviors in organizations (Turnley et al. 2003). The organization's fulfillment of its obligations will motivate the employees to keep performing activities which are beneficial to the organization as a return to the organization. They are also important to promote the participation in voluntary organizational context (Farmer and Fedor 1999). The effects of obligations have been confirmed in electronic virtual communities, and it is indicated that obligations are critical to the knowledge contribution activities in online communities. The open source community is an online social collective environment, it is reasonable to believe that a participant's obligation to the

community will induce his participation in the software development even beyond or over his self-interests. For these reasons, the following hypothesis is offered:

Hypothesis 6: A member's obligation to the open source community is positively related to his/her participation in the community.

3.9 Shared Values

Three components of identification that have been identified in the literature are similarity of values, membership in the organization, and loyalty toward the organization (Patchen 1970). Similarity of values is sometimes regarded as the same as joint goals. In this research shared values are distinguished from congruent goals and are defined as commonality in attitude, belief and interests among the individuals in an open source community. This definition of shared values is more ideology related, and separate from the specific targets of the project. Research has shown that people with similar attitudes, beliefs and values are more likely to become attached to one another (Manstead and Hewstone 1996), and a shared language and social, cultural, and religious background may play a part in binding individuals to a particular group.

People have the motivation to affiliate to collectives to meet their need of belongingness and social interaction. Lou and Luo (2000) and Li et al. (2005) found that relational factors like perceived critical mass, have significant on the usage of groupware and online community publication through their influence on perceived enjoyment or perceived usefulness. In the context of open source, shared values with other members in the same community may help satisfy the individual's internal need for social

belongingness, and make him feel the participation experience more enjoyable. So, the following hypothesis is offered:

Hypothesis 7: Shared values between an individual and others is positively associated with the member's enjoyment with the open source community.

The similarity-attraction paradigm posits that the degree to which members of a group are alike in terms of personal attributes represents an important basis of interpersonal attraction and cohesion, and attitude similarity has effects on the social integration at the group level (Van der Vegt 2002). Consistent with organizational culture literature, in which culture reflects a set of beliefs, expectations, and shared values that guides the behavior of an organization, it has been confirmed that people are attracted to organizations whose general core or dominant values they share. Shared values is considered to be a major basis for the development of social identification in a collective environment, including software development (Gefen and Ridings 2003).

Shared values is the glue to bind members in the community, because it reflects the similarity in belief, attitude and interests among them. It has been found that such perception of similarity may help the generation of a sense of community in both physical and online communities (Blanchard and Markus 2004). In the community context, perception of similarity is very important for the development and sustainability of the community, because there is no formal contractual relationship between the members and the organization, and no clear organizational boundary as in formal organizations, so the perception of shared values is a major factor to make the members feel they have things in common and belong to a same collective.

In the open source context, the shared values among members are expected to promote the interpersonal relationships and generation of the sense of oneness among the members in the same community.

Hypothesis 8a: Shared values between an individual and others is positively associated with the member's identification with the open source community.

Hypothesis 8b: Shared values between an individual and others is positively associated with the member's obligation to the open source community.

3.10 Congruence between individual and project goals

Goal congruence reduces conflicts and facilitates conflict resolution, which is very important to the success of software development in both traditional software engineering (Barki and Hartwick 1994; Barti and Hartwick 2001; Robey and Smith 1993) and in the open source context (Joode 2004; Sagers 2004). Here, the congruence between individual and project goals is defined as the degree and extent to which the developer perceives the targeted goal and major characteristics of the project are aligned with his/her needs and requirements. Interpersonal conflicts may generate negative emotion, and make the person feel interfered or frustrated (Barti and Hartwick 2001). In open source context, the software development and innovation depends on the cooperation of the participants. So, goal congruence is important for an individual's perceived enjoyment in open source participation. The following hypothesis is offered:

Hypothesis 9: Congruence between individual and project goals is positively associated with the member's enjoyment with the open source community.

Goal congruence is an important factor to determine a member's identification with a collective (Lee 1971). In the open source context, since the developers themselves are also users of the software, a major motivation for open source software development participation is the need of personal use (Hars and Ou 2002; Hann et al. 2004). So, the congruence between the developer's individual goals and the perceived project goals is expected to have great impact on the developer's attitude about the project, and consequently his/her identification with the community. Based on agency theory, the agent and the principal may hold different goals, and the goal incongruence lead to outcomes which are not desirable to the principal's interests. Such kind of incongruence happens in software development (Austin 2001). In non-profit or voluntary organizations, goal congruence is more important to link the participants with the organization since there is no formal contract or legal control systems to bind them together (Farmer and Fedor 1999; Meyers et al. 2001). In a virtual environment, perceived common goals are critical to the team cohesion and effectiveness of collective actions, because goal clarity helps to generate the feelings of interdependence and belonging to the same collective (Huang et al. 2003). Similar or congruent goals make the individual feel he/she has common fate or interests with the organization, which leads to his/her identification with the organization (Reade 2001).

In the open source context, the congruence between the individual and project goals is considered to be a major link which ties the individual to the project and other members in the same community, since it reflects the common interests among them. The relationship is expressed in the following hypothesis.

Hypothesis 10a: Congruence between individual and project goals is positively associated with the member's identification with the open source community.

Goal congruence is also related to expectation confirmation and satisfaction, which is the positive affective experienced by an individual in a relationship, and it is influenced by the extent to which the relationship fulfills the individual's most important needs (Rusbult et al. 1998). Satisfaction is an important in the mutuality between an individual and his/her organization, it is critical to the fulfillment of psychological contract, and is motivational factor for organizational citizenship behavior (Podsakoff et al. 2000). In the voluntary context, the organization's meeting of the participants' expectation is regarded as an important part in the fulfillment of its obligations, which will motivate the participants to fulfill their obligations by loyalty and more involvement (Farmer and Fedor 1999).

Organizational dependence is an important antecedent factor to identification and obligation (Allen and Meyer 1990). Goal congruence reflects the level of interdependence between a individual and others in the same organization, and it indicates the extent to which an individual believes the relationship with the collective can be counted on to satisfy his own needs. Mutual dependence is important for the quality of partnership (Lee and Kim 1999), and is expected to help generate a sense of moral obligations among people (Fairtlough 1994). In the open source context, goal congruence is expected to influence obligation through both the feelings of reciprocity and dependence. Perception of the congruence between his and the project goals is likely to affect his obligation to the community. So the following hypothesis is offered:

Hypothesis 10b: Congruence between individual and project goals is positively associated with the member's obligation to the open source community.

3.11 Trust

Trust plays a key role as a foundation for effective collaboration (Kramer 1999; Mayer et al. 1995; Rousseau et al. 1998) and is the salient factor in determining the effectiveness of many relationships. Trust is particularly important in newer organizational forms such as virtual collaborative relationships (Mcknight et al. 1998). In the virtual world, trust is a way of "managing people whom you do not see". It has been empirically confirmed that interpersonal trust significantly affects the performance of collaboration in virtual environment (Paul and McDaniel 2004; Jarvenpaa and Leidner 1998), since trust facilitates cooperation and knowledge sharing which is critical to innovation and learning.

Trust is difficult to develop in a virtual environment because of the lack of collocation (Jarvenpaa and Leidner 1998). However, with the interaction among online collaborators, relationships can be developed (Chidambaram 1996; Walther 1995) and trust can be formed (Jarvenpaa and Leidner 1998; Jarvenpaa et al. 2004; Ridings et al. 2002). In online communities, interpersonal trust acts as a relational tie to bind the members together and psychologically link the members to the community as a whole (Wasko et al. 2004). In the virtual community context, the generalized trust, which is trust towards other members in the same community as a whole, can be generated. The generalized trust plays an important role in affecting a member's attitude and affiliation to the online community (Wasko et al. 2004; Wasko et al. 2005).

Trust is critical to individual's satisfaction and relationship continuance in virtual collaboration context (Balasubramanian et al. 2003). Trust reduces the sense of uncertainty and increases the sense of control over the action being conducted, which is important for the positive affective emotion like enjoyment. In the context of open source, where there is no formal or legal contract to control or safeguard the exchange among the members, trust is critical for the generation of positive attitude towards the community, and makes the individual feel the participation experience more pleasant. So the following hypothesis is offered:

Hypothesis 11: A member's trust to others in the same community is positively associated with his/her enjoyment with the open source community.

Trust is expected to be a determinant of the member's identification with the collective. Trust is an important personal belief which impacts the attitudes to others and the organization as a whole, and it indicates a willingness of people to be vulnerable to others due to beliefs in their good intent and concern, competence and capability, and reliability (Mishra 1996). In a virtual collaboration environment trust is critical to the maintenance of long-term relationship and interdependence. Promoting the formation of trust is important for community members to generate positive attitudes to the community, and consequently form the feeling of belonging and attachment to the community as a whole. It is found that trust is important in the process of formation of the sense of oneness in virtual community (Blanchard and Markus 2004).

In the open source context, the members are globally dispersed and there is probably never a chance for face-to-face meetings, and the members do not know the

background of others in the same community. Trust is critical to hold them together for a common goal. Trust or the belief in others' ability, competence and integrity is necessary for a member to input his/her effort in the project and attach his/her own hope and interests to the fulfillment of the community goals. The open source community is an informal voluntary organization which has no formal or legal contracts to safeguard the exchange or guarantee the members' responsibilities in the software development, so trust is even more important to facilitate the building of relationship between the members and the community.

Interpersonal trust has both cognitive and affective foundations (Lewis and Wiegert 1985). Cognition-based trust comes from the beliefs of competence, reliability and dependability of others based on available knowledge and "good reasons" (Luhmann 1979; Zucker 1986). Affect-based trust consists of the emotional bonds between individuals (Lewis and Wiegert 1985), people make emotional investments in trust relationships, and such emotional ties link individuals and provide the basis for trust. It is verified by many studies that the interpersonal trust among individuals in organizations are characterized by the two dimensions of cognition-based and affect-based trust (McAllister 1995).

In the context of a virtual community, both cognitive and affective trust influence the relationships among members, and the production of trust results from the recognition, identification and emotional exchange which are the outcome of interactions (Blanchard and Markus 2004). In an open source community, both cognitive and affective trust can be developed among members with the interactions. The cognitive and affective trust in

others has an impact on the member's formation of a sense of belonging, and consequently affects his/her activities.

Hypothesis 12a: A member's trust to others in the same community is positively associated with his/her identification with the open source community.

Trust also plays a very important role in the exchange between persons. As partners develop increased trust in one another, they are likely to become more satisfied with the other partner, and depend more on one another (Wieselquist et al. 1999). Such increased dependence will strengthen the commitment to the relationship. It has been demonstrated that trust is the major determinant to satisfaction (Balasubramanian et al. 2003), and the fulfillment of psychological contract in virtual collaboration (Piccoli and Ives 2003).

In virtual communities, generalized trust, which is the trust towards others in the same community as a whole, is considered to be more important since trust between individuals is not as easy to be formed as in physical face-to-face environments (Wasko et al. 2004). Generalized trust will promote an individual's affective attitude towards the community as a whole, and make the individual to reciprocate to the community, not just particular others in the community. So, it is reasonable to believe that in open source context, trust towards other members in the same community will increase the individual's obligation to return to the community.

Hypothesis 12b: A member's trust to others in the same community is positively associated with his/her obligation to the open source community.

3.12 Perceived leader support

Perceived organizational support has been studied as exchanges between an employee and employing organization, it is related to the mutuality and reciprocity in organization. Perceived organizational support is highly related to leader-member exchange that refers to the exchanges between an employee and his supervisor because leader plays the critical role in administering or conducting the supports to the subordinates (Wayne et al. 1997). Here, perceived leader support is defined as the perception of work-related or emotional support a member received from the project leaders.

Volunteers involve in open source software projects mainly to meet their internal needs, such as recognition and sense of achievement. As in other organizations, leaders play an important role in promoting the satisfaction of members in a community. Leader's caring, respect, and work-related and emotional support are important to the feeling of the members. So, perceived leader support may make the members feel the participation experience more pleasant and enjoyable. The following hypothesis is offered:

Hypothesis 13: Perceived leader support is positively associated with a member's enjoyment with the open source community.

Eisenberger et al. (1986) argued that employees' belief concerning the extent to which the organization values their contributions and cares about their well-being underlie their inferences concerning their organizations' commitment to them, which in turn contribute to the employees' commitment to their organizations. Leaders play the

most important role in providing work-related and emotional support for the members in organizational context. Leader's support will not only motivate the members' reciprocity to the leader, but also promote the members' reciprocity to the organization as a whole (Podsakoff et al. 2000). It has been examined that relationships are developed between leaders and members in virtual collectives (Pauleen 2003), and leaders' social ability is critical to the effectiveness of virtual collaboration (Kayworth and Leidner 2001). In online community environment, where there is no clear boundary between the inside and outside, social support is more important for the generation of sense of belonging to the community, and leader's enthusiasm towards the members is necessary for the members' sense of community (Koh and Kim 2003).

Social support also plays an important role in the social exchange relationships between the members and organization. The principle of reciprocity suggests that individuals who receive high levels of social support may be motivated to reciprocate (Gouldner 1960). High levels of perceived social support create obligation, and members which are highly supported may feel an obligation to reciprocate to the employer by engaging in behaviors that support organizational goals (Wayne et al. 1997). Supervisor support impacts the developers' satisfaction and job anchor in software development (Jiang and Klein 1999). Perceived social support is also considered to be an important component in the psychological contract between member and organization; it is highly related to the psychological contract fulfillment which is critical to member loyalty and reciprocity in both formal and voluntary organizations (Farmer and Fedor 1999; Liao-Troth 2001; Turnley et al. 2003).

Open source community is an online voluntary organization, in which the participants take part in the software development not for monetary return, but mainly for self-enhancement. It is reasonable to believe that such exchange relationships can be generated between the project leaders and the members. And the supportive reactions from the leader will make the developer feel he/she is valued, included and respected in the community, which will enhance the obligation level through reciprocity. The following hypothesis is offered:

Hypothesis 14a: Perceived leader support is positively associated with a member's identification with the open source community.

Hypothesis 14b: Perceived leader support is positively associated with a member's obligation to the open source community.

3.13 Summary

This chapter has presented a research model for the impact of motivational factors on participation in the open source community. Reputation, software needs, learning purpose, enjoyment and relational factors, including Identification and obligation, are the central factors in the model since they are believed to be the major factors that determine volunteers' participative behavior in an online community for the development of software. The antecedents to these motivational factors, which include goal congruence, shared values, trust, and social support, are discussed.

CHAPTER IV

RESEARCH METHOD

4.1 Overview

A survey will be conducted for the empirical study. The constructs in the research model are measured using respondents' self-reports. A survey research design is used for this study because most constructs in the research model, including reputation gaining, enjoyment, identification, obligation, goal congruence, shared values, trust, and perceived support, are respondents' perception, belief, attitude and intention, which can only be measured through the respondents' report. Developers' participative behavior can also be measured through their self-report in response to the survey. In addition, it is ideal to study the open source communities in the real and natural settings, and it is infeasible to replicate the open source software development in experimental settings. Therefore, the survey method is the most desirable method for this study.

A Web survey is used for the data collection. It is demonstrated that a Web survey can increase the response rate. The survey questionnaire will be posted on the research website, so the respondents can go to the website and answer the questions online. The sample for this research will be obtained from sourceforge.net, the largest open source web site, and the response data will be analyzed using structural equation modeling.

4.2 Operationalization of Constructs

The constructs in the research model are assessed using multiple item measures. All constructs are measured based on well-established scales from information systems,

social psychology and organizational behavior. Some minor modifications or adaptations are made to the scales to make them fit the research context better. The measurements use a 1-7 likert scale. It is important to identify measures as either formative or reflective in type before data collection in the structural equations modeling context (Fornell and Bookstein 1982; Howell 1987). For formative measures, each item of the measure represents a single dimension. For reflective measures, the questionnaire responses are reflections of the unobservable construct if all the items are taken collectively.

4.2.1 Participative Behavior

Hertal et al. (2003) used "hours/week spent on Linux development" to measure the level of participation of Linux developers. Similar measurement can also be used for this study to measure an open source developer's level of involvement in the project. According to Hoegl and Gemuenden (2001), members' effort, mutual support, and initiatives are critical to the success of innovative projects. In open source software development, the voluntary developers' effort put into the project, helping each other and initiatives are determinants to the outcomes of the software development. To measure such behaviors, some items from the measurement of citizenship behaviors, including civic virtue and altruism are used and adapted. These items are developed and used in many studies like van Dyne et al. (1994), Bell and Menguc (2002), and Gefen and Ridings (2005).

1. How many hours/week do you spend on the project?
2. I put much effort into the project.
3. I fully support the project.

4. I make this project a high priority in my life.
5. I frequently contribute my knowledge to the project.
6. I would like to be a member in the project.

4.2.2 Reputation

To measure the motivation of reputation, this study adapts the scales from Constant et al. (1996). This measurement was used in some other studies like Wasko and Faraj (2005).

1. I earn respect from others by participating in the project.
2. I feel that participation in the project improves my status in the profession.
3. Participation in the project improves my reputation in the profession.

4.2.3 Enjoyment

To measure the motivation of enjoyment, this study uses the scale adapted from Agarwal and Karahanna (2000) and Davis et al. (1992).

1. The actual process of participating in the project is pleasant.
2. I have fun being a member of the project.
3. Participation in the project bores me (reverse coded).
4. Participation in the project provides me with a lot of enjoyment.

4.2.4 Identification with Open Source Community

To measure identification with open source community, this study uses the scale developed by Mael and Ashforth (1992). This measurement was used in some other studies like Wiesenfeld et al. (2001).

1. When I talk about the project, I usually say 'we' rather than 'they'.
2. The project's successes are my successes.
3. I am very interested in what others think about the project.
4. When someone praises the project, it feels like a personal compliment.
5. When someone criticizes the project, it feels like a personal insult.

4.2.5 Obligation to Open Source Community

To measure obligation to open source community, this study uses some items for normative commitment from Allen and Meyer (1990).

1. I feel a sense of obligation to continue participating in this project.
2. I believe that loyalty to this project is important.
3. It would be wrong for me to stop being a member in the project.
4. Jumping from this project to others does not seem right to me.

4.2.6 Shared Values

To measure shared values, this study uses the scale from Maxham and Netemeyer (2003).

1. Others in the project have the same values as I do with regard to open source software.

2. In general, my values and the values held by the project are very similar.
3. I believe in the same values held and promoted by the project.

4.2.7 Congruence between individual and project goals

To measure goal congruence, this study combines the items from Ybarra and Wiersema (1999) and Jap and Anderson (2003).

1. My goals for this project are shared by others.
2. My partners have similar motives for conducting this project.
3. I have compatible goals for the project with others.
4. My partners and I have different goals for the project. (reverse coded)
5. My partners support my objectives.

4.2.8 Trust

Both cognitive trust and affective trust are included in the research model. To measure cognitive and affective trust, this study uses the scales from McAllister (1995). These measurements have been used by many other studies for measurement of trust.

The scale for cognitive trust is:

1. The members in the project approach their jobs with professionalism and dedication.
2. I can rely on other members not to make my job more difficult by careless work.
3. Other members in the project can be respected as coworkers.

4. Other members whom I must interact are considered to be trustworthy.

The scale for affective trust is:

1. I can freely share ideas, feelings and hopes with others in the project.
2. I can talk freely to others in the project about difficulties I am having and know they will want to listen.
3. We would feel a sense of loss if one of us was transferred and we could no longer work together.
4. I would have to say I have made considerable emotional investment in working relationships with others in the project.

4.2.9 Perceived Leader Support

To measure perceived leader support, this study combines some items for measurement of perceived organizational support from Eisenberger et al. (1986) and leader-member exchange from Scandura and Graen (1984). These measurements have been used in some other studies like Wayne et al. (1997).

1. The leader(s) show very little concern for me. (reverse coded)
2. The leader(s) really care about my well-being.
3. The leader(s) strongly consider my goals and values.
4. The leader(s) care about my opinions.
5. The leader(s) is willing to help me perform my tasks to the best of my ability.
6. Help is available from the leader(s) when I have a problem.
7. The leader(s) recognize my potential.

4.3 Sampling and Data Collection

4.3.1 Site for Research

The largest open source website sourceforge.net is selected for data collection. Sourceforge.net provides free hosting to tens of thousands of open source projects, and is a centralized place for open source developers to meet online for open source software development. On April 4, 2005, there are 98,411 registered projects and 1,047,114 registered users on the website. These projects cover a wide range of software types, including games, multimedia, applications, network and Internet software, operating systems and server software, and vary in degrees of maturity such as planning, alpha and beta stages, and mature, stable software. The developers and users are globally distributed with various background. Each project has a folder on the website, project homepage, profile, developers information and software archives can be got from it, and the software can be freely downloaded. The webpage for an open source project on sourceforge.net is shown in Figure 4.1.

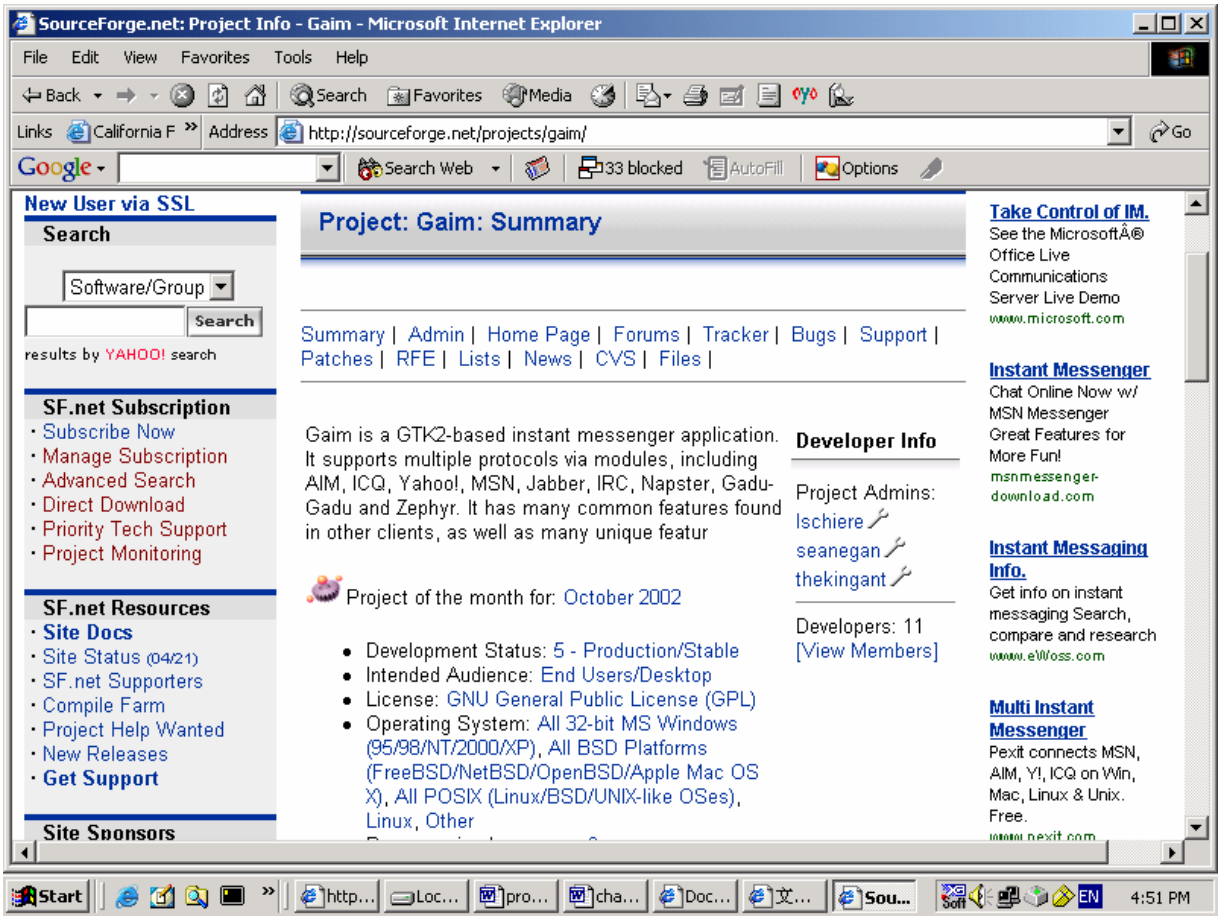

Figure 4.1 An Open Source Software Project Website

The project profile contains following information:

1. Project name
2. Registration date
3. Development status: indicated with a number from 1 to 7 (1-Planning; 2-Pre-Alpha; 3-Alpha; 4-Beta; 5-Production/Stable; 6-Mature; 7-inactive)
4. Intended audience: in one of the following categories
    - End users: Advanced end users; Developers; End users/desktop; Quality engineers; System administrators

- Industry or sector: Aerospace; Customer service; Education; Financial and insurance; Government; Healthcare; Information technology; Manufacturing; Non-profit organization; Religion; Science and research; Telecommunications

5. License type: GNU GPL; Apache; BSD, etc.
6. Operating system
7. Programming language
8. Topic: in one of the following categories

   Communications; Database; Desktop environment; Education; Formats and Protocols; Games/Entertainment; Internet; Multimedia; Office/Business; Printing; Religion/Philosophy; Scientific/Engineering; Security; Sociology; Software development; System; Terminals; Text editors.
9. User interface

The developers information contains:

1. Developer name
2. User name on the website
3. Role/position in the project
4. Email address
5. Skills

The project archives contain:

1. Software releases that can be downloaded freely
2. CVS repository containing the source codes
3. Mailing lists
4. Public forums

4.3.2 Subjects

The target subjects for this research are the voluntary developers of open source software. According to Koch (2004), the core developers make nearly eighty percent of the total contribution in code volume in an open source project. So the behaviors of core developers are critical to the success of an open source software development, and they are the focus in this study. The project leaders or administrators are the initiators or managers for the project, they are different from other volunteers in both motivations and attitude to the project, so they are not subjects for this study. The subjects for this study are the members who are voluntary to participate in the open source projects.

4.3.3 Sampling Procedure

The criteria for sampling are: (1) the sample has enough units to test the model; (2) the sample has enough diversity (variance on measures) to test the model; (3) the sample is representative to make inferences about the population.

The ongoing projects on the website sourceforge.net will be sampled for data collection. The advantage of using a site that hosts multiple projects is that data collection may be standardized, in that the same data is available for all projects. The disadvantage is that all projects all not included in the sample as a number of projects have their own

web sites, and thus are not listed on this site. In order to standardize data collection, and apply consistent criteria to the selection of projects, it is decided to investigate only projects hosted on Sourceforge. Although these projects and their members do not represent the totality of open source development, there are enough projects that they may fairly be considered representative of much of the larger body.

Projects are selected from Sourceforge.net. Among the projects, some of them may already be finished or abandoned, so there is no activity on them. To ensure only active ongoing projects are included in the sample, the selected projects must have some activities in the month before data collection in terms of contribution to the code repository; requests for bug fixes, support, patches or features; or in terms of page views.

This research investigates the voluntary developers' participative behavior. So the developers in the selected projects are subjects for the study.. Their email addresses on sourceforge will be used for contact.

Web survey will be administered for data collection. According to prior experience, web survey may lead to higher response rate since it is more convenient to the respondents (Faught et al. 2004). The survey questions will be posted on the researcher's web site. The questionnaire contains:

- Introduction to state the purpose of the research, the length of the survey, a request for the help from the respondents, and the incentives offered for completing the questionnaire.
- Requests for respondent's demographic information (age, sex, education)

- Questions about respondent's open source experience (how many years of open source participation; how many open source projects ever participate; how long in the current open source project)
- Questions described in section 4.2

Emails will be sent to the subjects to invite them to participate in the survey. The respondents can go to the research web site and answer the questions.

To consider the effects of repeated measures, it is necessary to know in which project each subject is working. So such information is needed to get in data collection.

4.4 Data Analysis Method

The research model is tested using structural equation modeling (SEM). SEM has been used widely in information systems research in past years. SEM-based procedures have some advantages over techniques such as principal components analysis, factor analysis, discriminant analysis, or multiple regression because of the greater flexibility that a researcher has for the interplay between theory and data.(Chin 1998).

SEM allows the simultaneous evaluation of the qualities of the measures and the causal relationships of the unobserved constructs. To be specific, a two-step analysis is adopted (Anderson and Gerbing 1988). Following this approach, the analysis of measures is separated from that of the structural model. The validity and reliability of measures are analyzed before the structural model is tested. Such approach provides greater confidence in the reliability and validity of the measures, and the relationships suggested by the structural model.

4.4.1 Basic Notions and Guidelines of the Measurement Model

The measurement model specifies the relations between the observable indicators and the latent constructs through the loadings of the observable indicators and their error terms (similar to confirmative factor analysis). There are two equations:

$$X = \Lambda_x \xi + \delta$$
$$Y = \Lambda_y \eta + \varepsilon$$

Where,

X = exogenous indicator

Y= endogenous indicator

ξ = exogenous construct

η = endogenous construct

Λ_x = matrix of the loadings for the exogenous indicators (element - $\lambda^{(x)}_{pm}$). Λ_x is a p x m matrix, where p = the number of exogenous construct indicators and m = the number of exogenous constructs.

Λ_y = matrix of the loadings for the endogenous indicators (element - $\lambda^{(y)}_{qn}$). Λ_y is a q x n matrix, where q = the number of endogenous construct indicators and n = the number of endogenous constructs.

In this study, multiple indicators are used to measure a latent construct. In order to put the latent construct on the same scale as the observed indicator, one indicator's coefficient (λ) is set to 1.00. During the measurement model phase, endogenous and exogenous constructs are not differentiated and all the items are treated as indicators of exogenous variables. Thus, one overall equation, $X = \Lambda_x \xi + \delta$, is achieved. Structural equation modeling aims to find a solution for this equation, given the hypothesized

measurement model's parameters, that provides a model-specified variance-covariance matrix, Σ, that best reproduces the observed variance-covariance matrix S.

SEM software also provides some measures of the overall fit of the measurement model and the structural model, such as chi-square χ^2, goodness-of-fit index (GFI), and root mean square error of approximation (RMSEA). General rules of thumb for model fit are: chi-square should be insignificant, fit indices, such as GFI, AGFI, NFI, NNFI, and CFI, should be greater than .90, and RMSEA should not be larger than 0.05 (Chin and Todd 1995). Further, SEM software identifies candidate items for deletion from the measurement model by assessing whether they (1) show several large residuals with other indicators, (2) display insignificant loadings for the expected construct, (3) share large and unexplained variance due to error with other indicants, or (4) share common variance with multiple indicators of some other constructs. However, decisions to delete items must also depend on consideration of the underlying theories from which the items are generated.

4.4.2 Scale Assessment and Validation

Based on the measurement model, convergent validity, discriminant validity, and reliability of all the scales can be analyzed. To evaluate convergent validity, this study follows the guidelines from Fornell and Larcker (1981): (1) composite reliability of each construct should exceed 0.80, (2) CFA item factor loadings should be significant and exceed 0.70, and (3) average variance extracted (AVE) for each construct should exceed 0.50. Discriminant validity can be assessed by comparing the shared variances between constructs with the average variance extracted from the individual constructs (Fornell and

Larcker 1981). Lower shared variances between constructs than the average variance extracted from the individual constructs suggest disciminant validity. Reliability is assessed using both item reliability and composite reliability. Item reliability indicates the amount of variance in an item due to the underlying construct rather than to error and can be obtained by squaring the factor loading. Fornell and Larcker (1981) recommends the value of 0.50 for item reliability. Composite reliability is calculated using the formula: $\rho = (\sum\lambda_I)^2 / ((\sum\lambda_I)^2 + \sum\theta_I)$, where λ_I refers to the ith factor loading and θ_I to the ith error variance. This coefficient has a similar interpretation as Cronbach's Alpha, except that it takes into account the actual factor loadings instead of assuming that each item is equally weighted in determining the composite. Nunnally (1978) suggested a minimum 0.70 for composite reliability.

4.4.3 Basic Notions and Guidelines of the Structural Model

The basic notation of the structural model is

$$\eta = \Gamma\xi + \beta\eta + \zeta$$

Where,

ξ = exogenous construct

η = endogenous construct

β = gives the relationships of endogenous to endogenous constructs (element - β_{nn}), β is a n x n matrix, where n = the number of endogenous constructs.

Γ = gives the relationships of exogenous to endogenous constructs (element - γ_{nm}), Γ is a n x m matrix, where n = the number of endogenous constructs and m = the number of exogenous constructs.

ζ = the distance term for the endogenous variables

According to Anderson and Gerbing (1988), if the analysis of the measurement model shows good model fit, the structural model can be analyzed with modifications of the measurement items.

Hypotheses will be tested using the structural model. If the structural model fit adequately with the data, and the paths in the research model are significant ($p < 0.05$), the hypotheses are supported.

Implications for theory and practices will be got from the results of data analysis.

4.4.4 Limitations of SEM

SEM, as commonly employed, has some limitations as data analysis method. It does not consider the problem of repeated measures. In this study, the responses from a same open source project are supposed to be dependent, which violates the assumption of SEM that all observations are independent. To solve this problem, a supplemental study is suggested to be conducted to the SEM analysis. The supplemental study will create some new data sets which contain only one observation from each project, so the observations in the same data set are supposed to be independent. Then the new data sets are analyzed to see if the results are consistent with the results of SEM.

CHAPTER V

DATA COLLECTION

5.1 Overview

This chapter describes how data are collected for the study. Ongoing projects on Sourceforge.net, the largest open source website, are sampled. And voluntary developers of the selected projects are contacted for response to the Web survey.

5.2 Sampling Procedure

The target for study in this research is the behaviors of voluntary developers. A stratified sampling procedure is used. Open source projects are selected first, then developers from the projects are contacted for survey response.

Projects are selected from Sourceforge.net. Among the projects, some of them may already be finished or abandoned, so there is no activity on them. To ensure only active ongoing projects are included in the sample, the selected projects must have some activities in the month before data collection in terms of contribution to the code repository; requests for bug fixes, support, patches or features; or in terms of page views. Since the research is related to the social relational factors in virtual communities, only open source projects with at least three participants are eligible for the study. Currently 591 projects meet these criteria, and they are identified for this study. These projects cover a wide range of topics, including communications, multimedia, internet, games, database, software development, operating systems, and business applications. And they are in various development phases, including planning, pre-alpha, alpha, beta, production,

and maturity. The projects are also with different license types, including GNU General Public License (GPL), GNU Library or Lesser General Public License (LGPL), BSD License, Mozilla Public License 1.1 (MPL 1.1), Artistic License, MIT License, and Apache License V2.0.

The target for this study is voluntary participants of open source projects, so only voluntary developers are considered as subjects for study. The project leaders or administrators have different motivations and play different role in the project development, so they are not considered in this study. The selected 591 projects have totally 7674 voluntary developers, and they are targeted as subjects for the study.

5.3 Pilot Study

To make sure that the survey questions can be understood correctly by the potential respondents, and to estimate the response rate, a pilot study was conducted. 20 projects with 451 developers are chosen from the 591 projects, and the developers are contacted through emails. They are invited to visit the research website, make comments on the survey questions, and answer the questionnaire online. 26 developers responded to the online survey, and some of them give feedback and comments on the survey through emails.

Some minor changes are made to the survey based on the feedback from the pilot study. And it also shows that a significant number of responses can be got from the potential respondents, and Web survey is a reasonable way to collect data in this study.

5.4 Data Collection

571 out of the 591 projects (not including the 20 projects for pilot study) are used for the data collection. These 571 ongoing projects have 7223 developers totally, which are the potential subjects for study. The email address of every developer is got from the project web pages on Sourceforge.net, and they are used for contacting the developers.

Email is sent to each of the 7223 developers, the content of the email is to explain the purpose of the research and invite them to offer help by participating in the Web survey response. In order to get higher response rate, one week later, a reminder email is sent to the developers to request them to answer the survey if they have not done that yet. 523 emails were returned or bounced back due to the reason of wrong address or security protection. So, 6700 emails are believed to have reached the potential respondents.

424 responses were received by the end of the data collection. Four of the responses are invalid due to missing answer to items. So, totally 420 responses can be used for analysis. The responses are from developers in 251 different projects, each of which has one or more responses.

5.5 Sample Characteristics

5.5.1 Project Sample Characteristics

The 251 open source projects on Sourceforge.net from which responses are collected cover a wide range of topics, in various development phases, and with different license types (see Appendix C for the list of projects). The statistical characteristics of the sample projects are shown in Table 5.1.

Table 5.1 Project Sample Characteristics

Development Status	Number (N=251)	Percentage
Planning	5	1.99%
Pre-alpha	5	1.99%
Alpha	27	10.76%
Beta	79	31.47%
Production/Stable	119	47.41%
Maturity	15	5.98%

Project Age	Number (N=251)	Percentage
<1 year	18	7.17%
1-2 years	38	15.14%
2-3 years	45	17.93%
3-4 years	46	18.33%
4-5 years	42	16.73%
5-6 years	52	20.72%
>6 years	10	3.98%

Community Size	Number (N=251)	Percentage
<= 10	101	40.24%
11-20	71	28.29%
21-30	34	13.55%
31-40	15	5.98%
41-50	9	3.59%
51-60	5	1.99%
61-70	5	1.99%
71-80	1	0.40%
81-90	5	1.99%
>= 91	5	1.99%

License Type	Number (N=251)	Percentage
Apache Software License	5	1.99%
Artistic License	4	1.59%
BSD License	26	10.36%
GNU General Public License (GPL)	150	59.76%
GNU Library or Lesser General Public License (LGPL)	30	11.95%
MIT License	5	1.99%
Mozilla Public License 1.1 (MPL 1.1)	4	1.59%
OSI-Approved Open Source	6	2.39%
Others	15	5.98%

Topic	Number (N=251)	Percentage
Business Applications	13	5.18%
Communications	26	10.36%
Database	25	9.96%
Desktop Environment	13	5.18%
Education	8	3.19%
Games/Entertainment	28	11.16%
Internet	34	13.55%
Multimedia	28	11.16%
Scientific/Engineering	11	4.38%
Software Development	47	18.73%
System	14	5.58%
Others	4	1.59%

5.5.2 Developer Sample Characteristics

The research is to study the behavior of voluntary developers. Valid responses from 420 developers are received in data collection, and they are the sample data for analysis. Some demographic data about the developers are obtained, and the statistical characteristics of the developer sample are shown in Table 5.2.

Table 5.2 Developer Sample Characteristics

Gender	Number (N=420)	Percentage
Male	410	97.62%
Female	10	2.38%

Age	Number (N=420)	Percentage
<20	37	8.81%
20-29	194	46.19%
30-39	140	33.33%
40-49	36	8.57%
>50	13	3.10%

Open Source Experience	Number (N=420)	Percentage
<6 months	63	15%
6-12 months	106	25.24%
1-2 years	112	26.67%
2-3 years	71	16.90%
>3 years	68	16.19%

The developers in the sample are various in gender, age and different in open source project participation experience.

5.6 Estimate Non-response Bias

The response rate is 6.3%, to make sure the respondents can represent the whole sample, it is necessary to estimate the non-response bias. There are three types of methods to estimate the non-response bias, which are comparison with known values, subjective estimates, and extrapolation (Armstrong and Overton 1977). In this study, extrapolation is chosen to compare the early and late responses.

Extrapolation methods are based on the assumption that subjects who respond less readily are more like non-respondents. “less readily” has been defined as answering later, or as requiring more prodding to answer. In this study, the responses are anonymous, and it is very difficult to obtain the information about the non-respondents. So extrapolation is used to compare the early and late responses. There are two waves of responses in this study, the first wave follows the first round of invitation emails, and the second wave follows the reminder emails. So the responses from the two different waves can be compared to see if there is significant difference for the item values, and the respondents in the second wave are believed to be more similar to the non-respondents. Among the 420 valid responses, 317 responses are early, and 103 responses are late.

The SAS GLM procedure is used for the multiple-testing. The results are shown in Table 5.3.

Table 5.3 Multiple-Testing Results

Item	N (Early)	Mean (Early)	N (Late)	Mean (Late)	F-Value	P-Value	Significant Difference
A1	317	2.74	103	2.85	2.54	0.11	N
A2	317	2.09	103	2.05	0.15	0.70	N

A3	317	4.24	103	4.04	0.04	0.85	N
A4	317	5.76	103	5.82	0.82	0.37	N
A5	317	3.74	103	3.62	0.00	0.99	N
A6	317	4.62	103	4.60	0.18	0.67	N
B1	317	5.08	103	4.85	0.16	0.69	N
B2	317	5.82	103	5.61	0.50	0.48	N
B3	317	5.04	103	5.16	1.96	0.16	N
B4	317	4.85	103	4.79	0.19	0.66	N
B5	317	4.67	103	4.68	0.63	0.43	N
C1	317	5.62	103	5.63	0.48	0.49	N
C2	317	5.69	103	5.54	0.15	0.70	N
C3	317	1.82	103	1.78	0.13	0.72	N
C4	317	5.10	103	5.14	0.77	0.38	N
D1	317	5.19	103	5.17	0.35	0.56	N
D2	317	4.67	103	4.55	0.00	0.95	N
D3	317	5.50	103	5.37	0.11	0.74	N
D4	317	4.68	103	4.83	2.06	0.15	N
D5	317	3.80	103	3.62	0.11	0.74	N
E1	317	4.67	103	4.68	0.50	0.48	N
E2	317	4.76	103	4.69	0.06	0.80	N
E3	317	3.74	103	3.93	2.54	0.11	N
E4	317	3.35	103	3.40	0.63	0.43	N
F1	317	5.07	103	4.83	0.63	0.43	N
F2	317	5.05	103	5.05	0.44	0.51	N
F3	317	5.20	103	5.15	0.16	0.69	N
G1	317	5.30	103	5.12	0.38	0.54	N
G2	317	5.09	103	4.81	1.92	0.17	N
G3	317	5.38	103	5.28	0.01	0.91	N
G4	317	3.23	103	2.98	0.81	0.37	N
G5	317	5.09	103	4.79	2.20	0.14	N
H1	317	5.63	103	5.58	0.13	0.71	N
H2	317	5.28	103	5.10	0.16	0.69	N
H3	317	5.82	103	5.74	0.00	0.95	N
H4	317	5.82	103	5.78	0.05	0.83	N
H5	317	5.84	103	5.69	0.27	0.61	N
H6	317	5.58	103	5.49	0.00	0.97	N
H7	317	4.54	103	4.40	0.04	0.84	N
H8	317	3.89	103	3.77	0.00	0.95	N
I1	317	2.68	103	2.46	0.55	0.46	N
I2	317	4.49	103	4.41	0.05	0.83	N
I3	317	4.72	103	4.69	0.26	0.61	N
I4	317	5.32	103	5.27	0.09	0.76	N
I5	317	5.32	103	5.17	0.17	0.68	N
I6	317	5.48	103	5.41	0.03	0.85	N
I7	317	5.07	103	5.87	0.52	0.47	N

Gender	317	1.00	103	1.00	3.61	0.06	N
Age	317	2.38	103	2.42	2.18	0.14	N

The results indicate that the items have no significant difference in values for the early respondents and late respondents, which are similar to the non-respondents. So the respondents in the study can represent the whole sample, and the conclusions from the responses can be generalized to the population.

5.7 Developer Participation and Project Success

The dependent variable in this study is voluntary developer's participation in open source project. The factor most concerned by the open source project management is the success of project. The underlying assumption for this study is that there is relationship between the level of developer participation and the success of project. To make the study better motivated, it is necessary to conduct empirical study to confirm the link between developer participation and project success.

Content analysis can be conducted since much information can be obtained directly from Sourceforge.met. Such information includes software download, software releases, project age, developer information, bug reports and fixing, feature requests and processing, patch report and processing, mailing list, forum message and CVS update. Developer participation and project success can be reflected through some of the information.

Number of software downloads shows the popularity of the open source software, so it is a major indicator of the project success. It is used in some prior studies as measure of open source project success (Long and Yuan 2005; Stewart et al. 2005). In the open

source community as showed in Figure 2.1, there are core and non-core or peripheral developers. The non-core developers make contribution through bug reporting, new feature requesting or suggesting, and patch reporting. They communicate with the core developers and with each other mainly through the public forum. The core developers take responsibility for fixing of bugs, processing of new features and code patches to update the CVS. They communicate with each other mainly through emails. So the activity level of core developers can be reflected through number of tracker closed (number of bugs fixed, features completed and patches added) and number of email messages. So in the empirical study, number of tracker closed and email messages are independent variable, and number of software downloads is dependent variable.

The 251 open source projects described above are chosen as sample for the empirical study. They cover a wide range of topics, license types, status, age and size. Since project age and number of developers may have impact on the dependent variable, software downloads, so they are control variables in the study. The number of trackers closed is got by the total number of trackers minus the number of trackers open. The descriptive statistics of the independent and dependent variables are shown in Table 5.4.

Table 5.4 Descriptive Statistics of Participative Activities and Software Downloads

Factor	Number	Mean	Standard Deviation	Median	Max. Value	Min. Value
Downloads	251	657,715	1,731,698	92,872	16,158,527	24
Email Messages	251	9,545	25,185	1,666	295,989	0
Tracker Closed	251	436	1,143	119	14,959	0

The 251 projects have enough variance in number of downloads, tracker closed and email messages (see Appendix D for software downloads and project participation activities). To test the relationship between participative activities and software downloads, a regression analysis is conducted, with number of tracker closed and number of email messages as independent variables, number of software downloads as dependent variable, and project age (number of days since registration) and number of developers as control variables. OLS regression is used for the analysis. The result of regression is shown in Table 5.5.

Table 5.5 Regression Analysis Result

Factor	DF	Parameter Estimate	Standardized Parameter	Standard Error	T Value	Pr > |t|
Email Message	1	13.20	0.19	4.31	3.06	0.0024*
Tracker Closed	1	534.76	0.35	91.46	5.85	<0.0001*

*P<0.01, R^2=0.20

The relationship between developer participation and project success is shown in Figure 5.1.

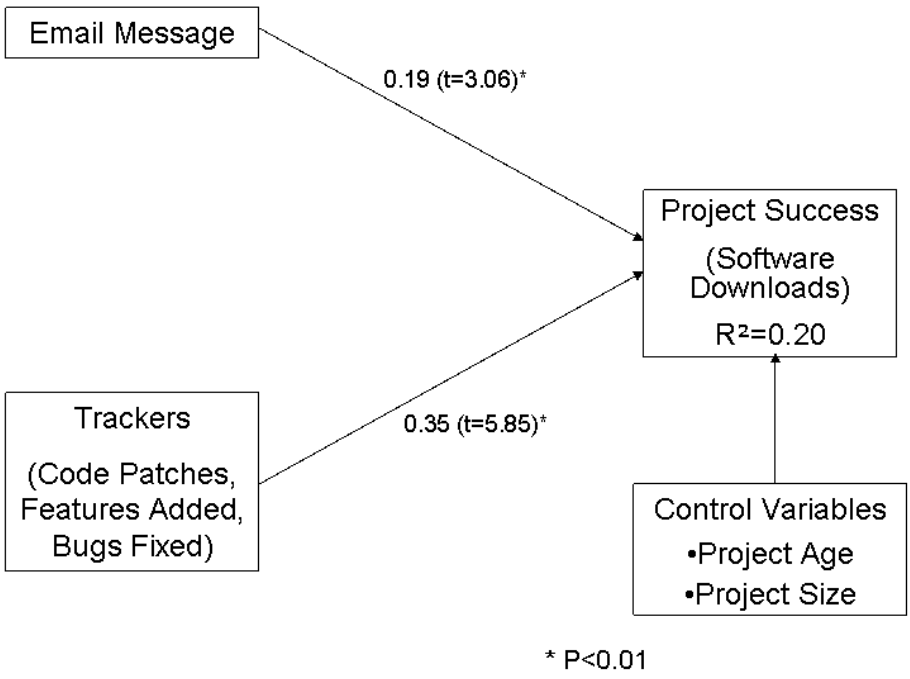

Figure 5.1 Developer Participation and Project Success

So, the number of email messages and trackers closed are positively related to the number of software downloads. It is reasonable to reach the conclusion that developers' participation has positive impact on the success of the open source project. To understand voluntary developers' participation behavior is important to enhance the success of open source projects.

CHAPTER VI

DATA ANALYSIS AND RESULTS

The purpose of this study is to investigate voluntary developers' participation in an open source project and its antecedent factors. In this section, the research model and hypotheses are tested based on the data collected. Structural equation modeling is used for data analysis. For the first step the measurement model is assessed, then the structural model is analyzed to test the hypotheses in the research model.

6.1 Data Analysis Method

Structural Equation Modeling (SEM) is used for data analysis. SEM is a methodology for representing, estimating, and testing a theoretical network of (mostly) linear relations between variables (Rigdon 1998). A structural equation model is a hypothesized pattern of directional and non-directional relationships among a set of observed (measured) and unobserved (latent) variables (MacCallum and Austin 2000). A measured variable is directly measured whereas a latent variable is not directly or exactly measured. Two main goals in SEM are (1) to understand the patterns of correlation among a set of variables and (2) to explain as much of their variance as possible with the model specified (Kline 1998).

All variables are classified as either dependent or independent. Any variable that has a one-way path pointing at it is classified as a dependent variable. All other variables are classified as independent variables. Relations between variables are of three types: (1) association e.g., correlation, covariance; (2) direct effect, directional relation between two

variables, e.g., independent and dependent variables; and (3) indirect effect, effect of an independent variable on a dependent variable through one or more intervening or mediating variables (Hoyle 1995).

SEM is used widely in information systems research as a comprehensive statistical approach. It has the ability for testing of measurement reliability, validity and the relationships among variables. Therefore, it is powerful for theory testing in empirical studies.

6.2 Dependent and Independent Variables

In the research model, the dependent variable is participation, the independent variables are extrinsic incentive factors (reputation, software needs, learning), an intrinsic motivation factor (enjoyment), social relational factors (identification, obligation), shared values, shared goals, trust and perceived leader support. The incentive factors, intrinsic motivation factor and social relational factors have direct effect on the dependent variable. The relationships between shared values and participation, between shared goals and participation, between trust and participation, between perceived leader support and participation are mediated through enjoyment, identification and obligation.

All these variables are latent variable since they are not measured directly, but reflected through some other observed items. The variables and the corresponding measurement items in the survey questionnaire (See Appendix B) are shown in Table 6.1.

Table 6.1 List of Variables and Measurement Items

Variable	Measurement Item
Participation	A2, A3, A4, A5, A6
Software Needs	B1
Learning	B2
Reputation	B3, B4, B5
Enjoyment	C1, C2, C3, C4
Identification	D1, D2, D3, D4, D5
Obligation	E1, E2, E3, E4
Shared Values	F1, F2, F3
Shared Goals	G1, G2, G3, G4, G5
Trust	H1, H2, H3, H4, H5, H6, H7, H8
Perceived Leader Support	I1, I2, I3, I4, I5, I6, I7

6.3 Reliability

Reliability refers to the accuracy and precision of a measurement procedure, or how well the instrument measures what it purports to measure (Thorndike et al. 1991). Reliability can be assessed by repeating the same test or measure; administering an equivalent form; or using single-administration methods like (a) subdividing the test into two or more equivalent parts, and (b) internal consistency measured with Cronbach's coefficient alpha. Cronbach's alpha is the most commonly used for assessment of reliability because its convenience and efficiency.

According to Chin (1998), Cronbach's alpha of at least 0.70 is a recommended value for reliable construct. To test the reliability of measurement for this study,

Cronbach's alpha was calculated with SAS procedure PROC CORR. Reliability of nine factors is shown in Table 6.2.

Table 6.2 Reliability of Factors

Factor	Measurement Item	Cronbach's Alpha
Participation	A2, A3, A4, A5, A6	0.872
Reputation	B3, B4, B5	0.878
Enjoyment	C1, C2, C3, C4	0.853
Identification	D1, D2, D3, D4, D5	0.828
Obligation	E1, E2, E3, E4	0.804
Shared Values	F1, F2, F3	0.894
Shared Goals	G1, G2, G3, G4, G5	0.790
Trust	H1, H2, H3, H4, H5, H6, H7, H8	0.860
Perceived Leader Support	I1, I2, I3, I4, I5, I6, I7	0.910

The results indicate that the composite reliability value ranges from 0.790 to 0.910. Therefore the measurement exceeds the requirement for reliability.

6.4 Exploratory Factor Analysis

The research model include eleven constructs, which are participation, software needs, learning, reputation, enjoyment, identification, obligation, shared values, shared goals, trust, and perceived leader support. The measurement scale is developed for these constructs. The scale has a total of 45 items. An exploratory factor analysis was conducted to test the dimensionality of the original scale by PROC FACTOR procedure. The loadings of items from exploratory factor analysis are shown in Table 6.3.

Table 6.3 Exploratory Factor Analysis Results

Item	Factor1	Factor2	Factor3	Factor4	Factor5	Factor6	Factor7	Factor8	Factor9	Factor10	Factor11
A2	0.0646	0.0452	0.0557	**0.7940**	0.1098	0.0952	0.0457	0.1186	0.0857	0.15395	-0.0091
A3	0.1660	0.0858	0.1073	**0.8097**	0.2105	0.2085	0.0468	0.1572	0.0286	0.04819	0.01060
A4	0.0895	0.1642	0.3907	0.4834	0.0626	-0.056	0.1096	0.0830	0.3776	0.01344	0.07568
A5	0.1621	0.1197	0.1586	**0.7492**	0.2423	0.1585	0.0949	0.2535	0.0863	0.10057	0.04216
A6	0.1320	0.1025	0.0609	**0.7633**	0.2013	0.2317	0.1661	0.1206	0.0174	0.15945	0.00921
B1	-0.072	0.1027	0.0701	0.0056	0.2467	0.0025	0.1130	0.0922	0.0208	0.15981	**0.77419**
B2	0.0787	0.1758	0.2875	0.1497	**0.5170**	0.0529	0.2085	0.1406	0.0217	0.11582	0.28345
B3	0.2084	0.1157	0.1383	0.2415	**0.6609**	0.2459	0.1497	0.0419	0.1136	0.04922	-0.0455
B4	0.0764	0.1162	0.0945	0.1939	**0.8364**	0.1678	0.0030	0.1435	0.1077	0.04065	0.05637
B5	0.0851	0.0891	0.0800	0.1385	**0.8524**	0.1395	0.0052	0.1652	0.1064	0.03490	0.03724
C1	0.2656	0.2459	**0.6979**	0.0561	0.1671	0.0782	0.1775	-0.035	0.1125	0.06200	-0.0216
C2	0.2576	0.2379	**0.6989**	0.1046	0.2313	0.2078	0.2362	0.0503	0.0977	0.13973	-0.0755
C3	0.1514	0.2238	**0.7059**	0.1447	-0.029	0.0652	-0.046	0.0507	0.1125	-0.06000	0.20691
C4	0.2570	0.1556	**0.6544**	0.1532	0.2372	0.1698	0.1318	0.0704	0.1572	0.24477	-0.0165
D1	0.1650	0.0148	0.1847	0.3390	0.0714	**0.6103**	0.1717	0.0452	0.0061	0.23063	0.11714
D2	0.0981	0.0572	0.1409	0.2810	0.2029	**0.7002**	0.1733	0.1597	0.1506	0.12846	0.04131
D3	0.0456	0.1952	0.3691	0.1933	0.1766	0.3669	0.2052	0.2199	0.2143	0.08632	-0.0140
D4	0.1693	0.0835	0.0986	0.2389	0.2346	**0.7277**	0.1355	0.2177	0.1114	0.07490	-0.0000
D5	0.1032	0.1128	0.0229	-0.049	0.1141	**0.6557**	0.0128	0.2706	0.0942	0.04198	0.03632
E1	0.1630	0.1644	0.1057	0.1644	0.1575	0.2884	0.1958	**0.6065**	0.0512	-0.06262	0.00717
E2	0.1683	0.1711	0.2005	0.0973	0.1484	0.1509	0.2028	**0.6995**	0.0853	0.10504	-0.0481
E3	0.0221	0.0827	-0.002	0.0891	0.0648	0.1774	0.0462	**0.7921**	0.0734	0.07766	0.02688
E4	0.0778	0.0235	-0.078	0.1919	0.1084	0.0887	0.0020	**0.7280**	0.1764	0.15915	0.15120
F1	0.1869	0.2221	0.0793	0.0419	0.1205	0.1540	0.1821	0.1457	**0.7359**	0.05851	0.08411
F2	0.1912	0.1569	0.1358	0.0889	0.1053	0.1270	0.2655	0.1103	**0.8028**	0.07553	0.06719
F3	0.1725	0.1571	0.1960	0.0427	0.1139	0.0909	0.2545	0.1323	**0.7899**	0.07632	-0.0055
G1	0.2177	0.1337	0.1211	0.1406	0.0602	0.0790	**0.7565**	0.1044	0.2565	0.07863	0.09080
G2	0.1627	0.0316	0.1023	0.0855	0.0694	0.2575	**0.6962**	0.1269	0.2740	0.10337	0.14190
G3	0.1576	0.3515	0.1322	0.1637	0.0729	0.0834	**0.6517**	0.1609	0.2677	0.02024	0.11342
G4	0.2683	0.1322	0.0253	0.0786	-0.194	0.1910	0.1341	0.0237	0.1810	-0.25826	0.54864
G5	0.2463	0.3418	0.1983	0.0509	0.1156	0.1979	0.4687	0.1249	0.1873	0.14026	-0.0746
H1	0.2853	**0.7071**	0.1427	0.0709	0.1703	0.0707	0.0506	0.1012	0.1770	-0.02221	0.10257
H2	0.2054	**0.7010**	0.1279	0.0037	0.0826	-0.009	0.0332	0.1563	0.0785	0.00925	0.01046
H3	0.2185	**0.7407**	0.1119	0.1141	0.1388	0.1550	0.1568	0.0692	0.1247	0.01031	0.03247
H4	0.2396	**0.7668**	0.2480	0.1090	0.0601	0.0801	0.0861	0.0735	0.1800	0.08708	0.06785
H5	0.2358	**0.5506**	0.2221	0.1822	0.0280	0.0802	0.3092	0.0207	0.0187	0.31365	0.10777
H6	0.3106	**0.5057**	0.2309	0.1029	-0.010	0.0585	0.2156	0.0289	0.1090	0.35379	0.10096
H7	0.2483	0.2426	0.1348	0.1211	0.1064	0.2243	0.1097	0.2043	0.2372	**0.65538**	0.07101
H8	0.2590	0.0356	0.1005	0.2584	0.1057	0.2786	0.1452	0.2347	0.0446	**0.66959**	-0.0093
I1	**0.6745**	0.1733	0.1554	0.0904	-0.013	0.1439	-0.086	-0.035	0.1634	0.05411	0.17871

I2	**0.7064**	0.1930	0.0285	0.0893	0.1096	0.1440	0.0019	0.0626	0.2211	0.21431	-0.0696
I3	**0.7277**	0.1666	0.1298	0.1905	0.0793	0.1549	0.1357	0.1387	0.1495	0.16085	-0.0581
I4	**0.7145**	0.3229	0.2055	0.1561	0.0988	0.0372	0.2255	0.1072	0.0902	0.03268	-0.0259
I5	**0.7023**	0.2621	0.3026	0.0166	0.0987	0.0066	0.2241	0.1966	0.0679	-0.01523	0.07285
I6	**0.6434**	0.3264	0.3124	-0.063	0.1475	0.0090	0.2382	0.1451	0.0227	-0.04055	0.09799
I7	**0.7370**	0.1825	0.0518	0.2083	0.1123	0.1572	0.2571	0.0480	0.0533	0.14487	-0.0150

Fornell and Larcker (1981) suggest that all the item loadings in the CFA model should be significant and exceed 0.7. Since the purpose of the exploratory factor analysis is to preliminarily test the dimensionality of the measurement scale, we adopt 0.50 as the threshold value for item loadings. The results of the exploratory factor analysis indicate that the measurement scale which contains 45 items has 11 dimensions. The items for software needs, enjoyment, obligation, shared values, and perceived leader support show satisfactory loadings. Item A4 for participation, item D3 for identification, item G4 and G5 for shared goals should be removed due to their low loadings. Item B2 for learning shows high convergence with the items for reputation (B3, B4, B5), this is interpretable from a theoretical perspective because many volunteers participate in open source projects to learn programming skills, which may help promote their professional status. So the items for learning and reputation can be combined as one factor, which is named as professional benefits. The items for trust (H1-H8) show two dimensions, which are consistent with the two types of trust: cognitive and affective trust.

Based on the results of exploratory factor analysis, eleven factors are obtained for further analysis: participation (A2, A3, A5, A6), software needs (B1), professional benefits (B2, B3, B4, B5), enjoyment (C1, C2, C3, C4), identification (D1, D2, D4, D5), obligation (E1, E2, E3, E4), shared values (F1, F2, F3), shared goals (G1, G2, G3),

cognitive trust (H1, H2, H3, H4, H5, H6), affective trust (H7, H8), and perceived leader support (I1, I2, I3, I4, I5, I6, I7).

6.5 Specification of the Measurement Model

SEM uses some measures of the overall fit of the measurement model, such as chi-square $\chi 2$, goodness-of-fit index (GFI), and root mean square error of approximation (RMSEA). General rules of thumb for model fit are: chi-square should be insignificant, fit indices, such as GFI, AGFI, NFI, NNFI, and CFI, should be greater than 0.90, and RMSEA should not be greater than 0.05 (Chin and Todd 1995).

To assess the measurement model, a confirmatory factor analysis was conducted using SAS PROC CALIS procedure. The results show a chi-square of 1844.31 with 764 degree of freedom ($p < 0.0001$). Other indices include Goodness-of-Fit Index (GFI = 0.8181), Adjusted Goodness-of-Fit Index (AGFI = 0.7850), Normed Fit Index (NFI = 0.8499), Non-normed Fit Index (NNFI = 0.8935), Comparative Fit Index (CFI = 0.9055), Root Mean Square Residual (RMR = 0.0603), and root mean square error approximation (RMSEA = 0.0581). The results suggest the need for further purification of indicators.

SEM identifies candidate items for deletion from the measurement model by assessing whether they (1) show several large residuals with other indicators, (2) display insignificant loadings for the expected construct, (3) share large and unexplained variance due to error with other indicants, or (4) share common variance with multiple indicators of some other constructs. However, decisions to delete items must also depend on consideration of the underlying theories from which the items are generated.

To improve the measurement model, following steps are taken:

1. The indicator B2 shares large residuals with other indicators and has a low loading (0.5409). It is deleted from the model. After this step, RMSEA is 0.0569.
2. The indicator B3 shares large residuals with other indicators and has a low loading (0.6970). It is deleted from the model. After this step, RMSEA is 0.0563.
3. The indicator E3 shares large residuals with other indicators and has a low loading (0.6770). It is deleted from the model. After this step, RMSEA is 0.0558.
4. The indicator H6 shares large residuals with other indicators and has a low loading (0.6983). It is deleted from the model. After this step, RMSEA is 0.0543.
5. The indicator H5 shares large residuals with other indicators and has a low loading (0.6915). It is deleted from the model. After this step, RMSEA is 0.0535.
6. The indicator E4 shares large residuals with other indicators and has a low loading (0.5798). It is deleted from the model. After this step, RMSEA is 0.0539.
7. The indicator C3 has a low loading (0.5825), D5 has a low loading (0.5406), H2 has a low loading (0.6648), I1 has a low loading (0.6173). They are deleted from the model. After this step, RMSEA is 0.0563.
8. The indicator I2 shares large residuals with other indicators and has a low loading (0.6995). It is deleted from the model. After this step, RMSEA is 0.0535.
9. The indicator I7 shares large residuals with other indicators. It is deleted from the model. After this step, RMSEA is 0.0513.
10. The indicator I3 shares large residuals with other indicators. It is deleted from the model. After this step, RMSEA is 0.0471.

After these steps, all item loadings are above 0.70. It shows a chi-square of 620.98 with 322 degrees of freedom ($P < 0.001$), and the ratio of chi-square to degrees-of-

freedom is 1.929, which is within the suggested value of 3 (Carmines and McIver 1981).RMSEA is 0.0471, GFI is 0.9087, AGFI is 0.8766, RMR is 0.0411, NFI is 0.9260, NNFI is 0.9528, CFI is 0.9626. Compared to commonly accepted values suggested in the literature (e.g., Chau 1997), all measures suggest a good fit of the measurement model.

Table 6.4 shows the specification process for the measurement model.

Table 6.4 Measurement Model Specification Process

Step	Changes From Previous Step	X^2	df	RMSEA	NFI	NNFI	GFI	CFI
1	None	1844.31	764	0.0581	0.8499	0.8935	0.8181	0.9055
2	Delete B2	1707.63	724	0.0569	0.8580	0.9006	0.8244	0.9122
3	Delete B3	1595.48	685	0.0563	0.8632	0.9048	0.8302	0.9164
4	Delete E3	1491.19	647	0.0558	0.8688	0.9090	0.8353	0.9206
5	Delete H6	1363.57	610	0.0543	0.8761	0.9157	0.8448	0.9268
6	Delete H5	1262.16	574	0.0535	0.8817	0.9202	0.8532	0.9312
7	Delete E4	1195.27	539	0.0539	0.8859	0.9221	0.8570	0.9333
8	Delete C3, D5, H2, I1	952.28	409	0.0563	0.9005	0.9274	0.8684	0.9401
10	Delete I2	833.20	379	0.0535	0.9095	0.9362	0.8808	0.9480
11	Delete I7	735.97	350	0.0513	0.9162	0.9425	0.8931	0.9538
12	Delete I3	620.98	322	0.0471	0.9260	0.9528	0.9087	0.9626

Now, the measurement model has 29 items: A2, A3, A5, A6, B1, B4, B5, C1, C2, C4, D1, D2, D4, E1, E2, F1, F2, F3, G1, G2, G3, H1, H3, H4, H7, H8, I4, I5, I6. The constructs and items are showed in Table 6.5.

Table 6.5 Construct and Items

Construct	Item	Question
Participation	A2	How many hours/week do you spend on the project?
	A3	I put much effort into the project.
	A5	I make this project a high priority in my life.
	A6	I frequently contribute my knowledge to the project.
Software Needs	B1	I personally need the software being developed.
Professional Benefits	B4	I feel that participation in the project improves my status in the profession.
	B5	Participation in the project improves my reputation in the profession.
Enjoyment	C1	The actual process of participating in the project is pleasant.
	C2	I have fun being a member of the project.
	C4	Participation in the project provides me with a lot of enjoyment.
Identification	D1	When I talk about the project, I usually say ‘we’ rather than ‘they’.
	D2	The project’s successes are my successes.
	D4	When someone praises the project, it feels like a personal compliment.
Obligation	E1	I feel a sense of obligation to continue participating in this project.
	E2	I believe that loyalty to this project is important.
Shared Value	F1	Others in the project have the same values as I do with regard to open source software.
	F2	In general, my values and the values held by the project are very similar.
	F3	I believe in the same values held and promoted by the project.

Shared Goals	G1	My goals for this project are shared by others.
	G2	My partners have similar motives for conducting this project.
	G3	I have compatible goals for the project with others.
Cognitive Trust	H1	The members in the project approach their jobs with professionalism and dedication.
	H3	Other members in the project can be respected as coworkers.
	H4	Other members with whom I must interact are considered to be trustworthy.
Affective Trust	H7	I would feel a sense of loss if one of us was transferred and we could no longer work together.
	H8	I would have to say I have made considerable emotional investment in working relationships with others in the project.
Leader Support	I4	The leader(s) care about my opinions.
	I5	The leader(s) is willing to help me perform my tasks to the best of my ability.
	I6	Help is available from the leader(s) when I have a problem.

6.6 Scale Assessment and Validation

Based on the measurement model, convergent validity, discriminant validity, and reliability of the scales can be analyzed. According to Chin (1998), Cronbach's alpha 0.70 is the recommended value for construct reliability, and item loading should be greater than 0.70 for convergent validity. The item loadings and reliability of constructs are showed in Table 6.6.

Table 6.6 Item Loadings and Construct Reliability

Construct	Item	Mean	Standard Deviation	Standard Loading	t-value	R^2	Cronbachs Alpha
Participation	A2	2.2476	1.3093	0.7515	8.97	0.56	0.8969
	A3	4.4500	1.9638	0.8920	8.92	0.80	
	A5	3.9500	1.8344	0.8979	8.90	0.81	
	A6	4.8548	1.8449	0.7996	9.11	0.64	
Software Needs	B1	5.2548	1.7680	1.0000		1.00	
Professional Benefits	B4	5.0310	1.4999	0.9468	8.09	0.90	0.9207
	B5	4.8691	1.4992	0.9009	7.99	0.81	
Enjoyment	C1	5.7691	1.1061	0.7956	9.18	0.63	0.8686
	C2	5.8048	1.1268	0.9138	9.20	0.84	
	C4	5.2810	1.3025	0.8022	9.19	0.64	
Identification	D1	5.3881	1.5431	0.7407	9.11	0.55	0.8388
	D2	4.8333	1.5044	0.8634	9.53	0.75	
	D4	4.9238	1.5721	0.7993	9.38	0.64	
Obligation	E1	4.8691	1.5229	0.7833	9.26	0.61	0.7677
	E2	4.9310	1.4235	0.7972	9.30	0.64	
Shared Values	F1	5.1857	1.3068	0.7592	8.93	0.58	0.8943
	F2	5.2119	1.2263	0.9395	8.51	0.88	
	F3	5.3381	1.1704	0.8998	8.60	0.81	
Shared Goals	G1	5.4095	1.1369	0.8289	9.50	0.69	0.8437
	G2	5.1786	1.1802	0.7670	9.28	0.59	
	G3	5.4952	1.0444	0.8177	9.47	0.67	
Cognitive Trust	H1	5.7691	1.1690	0.7580	9.18	0.57	0.8465
	H3	5.9381	1.0437	0.8046	9.36	0.65	
	H4	5.9429	0.9948	0.8742	9.49	0.76	
Affective Trust	H7	4.6952	1.4729	0.8234	9.43	0.68	0.7996
	H8	4.0571	1.5392	0.8097	9.39	0.66	
Leader Support	I4	5.4643	1.1831	0.8035	9.16	0.65	0.8909

	I5	5.4524	1.2796	0.9103	9.02	0.83	
	I6	5.6214	1.2250	0.8644	9.11	0.75	

The item loadings range from 0.7515 to 1.0000, which suggests that the factor loadings are large and the items loaded as intended for every construct. The t-values represent the large sample t-tests of null hypotheses that the factor loadings are zero in the population. All the t values are greater than 1.96, which indicates that the parameters estimated for factor loadings are statistically significant. Higher R-square values suggest that indicators are good measures of the constructs. All the R-square values are found to be greater than 0.55 supporting the assertion that the indicators used in this study are good measures of the factors. The Cronbach's alpha ranges from 0.7677 to 0.9207, which is above the cut-off value of 0.70. Thus the convergent validity and reliability of the constructs are confirmed. The correlation matrix for the items is shown in Table 6.8.

Tests for discriminant validity are conducted by testing each pair of constructs for unidimensionality. The tests involve considering only two constructs at a time. Two estimated constructs are included in a measurement model by constraining the estimated correlation parameter between these two constructs to 1.0. Then these two constructs are included in another measurement model with the correlation parameter unconstrained. A chi-square difference is obtained from the two chi-square values of these two models. A significant chi-square difference indicates discriminant validity between the pair of constructs (Anderson and Gerbing 1988).

Table 6.7 Discriminant Validity of Constructs

Construct	Freed Model		Constrained Model		Difference	
	d.f.	χ^2	d.f.	χ^2	d.f.	χ^2
Participation & Professional Benefits	8	11.91	9	465.67	1	453.76
Participation & Enjoyment	13	27.50	14	539.85	1	512.35
Participation & Identification	13	49.40	14	316.46	1	267.06
Participation & Obligation	8	17.19	9	157.08	1	139.89
Participation & Shared Values	13	18.98	14	780.12	1	761.14
Participation & Shared Goals	13	26.12	14	451.42	1	425.30
Participation & Cognitive Trust	13	26.24	14	496.51	1	470.27
Participation & Affective Trust	8	13.81	9	174.28	1	160.47
Participation & Leader Support	13	49.86	14	448.11	1	398.25
Professional Benefits & Enjoyment	4	12.14	5	483.23	1	471.09
Professional Benefits & Identification	4	7.98	5	402.11	1	394.13
Professional Benefits &Obligation	1	4.36	2	166.25	1	161.89
Professional Benefits & Shared Values	4	3.54	5	513.79	1	510.25
Professional Benefits & Shared Goals	4	5.67	5	485.62	1	479.95
Professional Benefits & Cognitive Trust	4	11.25	5	494.52	1	483.27
Professional Benefits & Affective Trust	1	0.75	2	210.92	1	210.17
Professional Benefits & Leader Support	4	13.76	5	530.38	1	516.62
Enjoyment & Identification	8	37.61	9	381.30	1	343.69
Enjoyment & Obligation	4	9.02	5	164.56	1	155.54
Enjoyment & Shared Values	8	23.97	9	511.79	1	487.82
Enjoyment & Shared Goals	8	8.47	9	342.94	1	334.47
Enjoyment & Cognitive Trust	8	9.44	9	312.78	1	303.34

Enjoyment & Affective Trust	4	24.17	5	185.45	1	161.28
Enjoyment & Leader Support	8	21.19	9	359.74	1	338.55
Identification & Obligation	4	13.18	5	129.44	1	116.26
Identification & Shared Values	8	15.55	9	437.64	1	422.09
Identification & Shared Goals	8	23.23	9	346.78	1	323.55
Identification & Cognitive Trust	8	8.06	9	436.23	1	428.17
Identification & Affective Trust	4	9.91	5	137.88	1	127.97
Identification & Leader Support	8	20.03	9	466.24	1	446.21
Obligation & Shared Values	4	4.32	5	162.86	1	158.54
Obligation & Shared Goals	4	6.58	5	140.95	1	134.37
Obligation & Cognitive Trust	4	5.57	5	151.55	1	145.98
Obligation & Affective Trust	1	0.06	2	116.39	1	116.33
Obligation & Leader Support	4	3.85	5	153.27	1	149.42
Shared Values & Shared Goals	8	11.55	9	268.54	1	256.99
Shared Values & Cognitive Trust	8	22.48	9	420.92	1	398.44
Shared Values & Affective Trust	4	5.37	5	208.26	1	202.89
Shared Values & Leader Support	8	19.48	9	616.82	1	597.34
Shared Goals & Cognitive Trust	8	44.31	9	356.11	1	311.80
Shared Goals & Affective Trust	4	6.80	5	17058	1	163.78
Shared Goals & Leader Support	8	25.14	9	367.88	1	342.74
Cognitive Trust & Affective Trust	4	3.44	5	198.24	1	194.80
Cognitive Trust & Leader Support	8	45.19	9	274.57	1	229.38
Affective Trust & Leader Support	4	13.23	5	203.78	1	190.55

Considering each pair of constructs, all chi-square differences range from 116.26 to 761.14 ($p<0.001$), thus suggesting sufficient discriminability between all constructs.

Table 6.8 Correlation Matrix

	A2	A3	A5	A6	B1	B4	B5	C1	C2	C4	D1	D2	D4	E1	E2
A2	1.000														
A3	0.674	1.000													
A5	0.684	0.804	1.000												
A6	0.594	0.721	0.697	1.000											
B1	0.097	0.124	0.208	0.131	1.000										
B4	0.323	0.407	0.435	0.404	0.202	1.000									
B5	0.277	0.365	0.414	0.346	0.202	0.853	1.000								
C1	0.183	0.268	0.321	0.254	0.142	0.270	0.275	1.000							
C2	0.292	0.363	0.421	0.355	0.102	0.367	0.349	0.743	1.000						
C4	0.302	0.366	0.440	0.376	0.150	0.388	0.381	0.618	0.725	1.000					
D1	0.405	0.423	0.425	0.513	0.156	0.314	0.279	0.261	0.416	0.431	1.000				
D2	0.371	0.490	0.479	0.471	0.182	0.403	0.373	0.259	0.417	0.398	0.664	1.000			
D4	0.362	0.496	0.483	0.503	0.158	0.410	0.398	0.323	0.409	0.408	0.550	0.692	1.000		
E1	0.281	0.372	0.441	0.392	0.163	0.330	0.317	0.254	0.319	0.323	0.334	0.435	0.475	1.000	
E2	0.274	0.345	0.411	0.332	0.150	0.321	0.356	0.278	0.381	0.384	0.310	0.390	0.410	0.624	1.000
F1	0.199	0.212	0.304	0.227	0.182	0.270	0.256	0.322	0.368	0.327	0.259	0.384	0.353	0.324	0.326
F2	0.229	0.247	0.309	0.287	0.185	0.262	0.255	0.355	0.381	0.420	0.268	0.384	0.372	0.329	0.353
F3	0.210	0.220	0.300	0.249	0.144	0.260	0.251	0.370	0.432	0.434	0.226	0.329	0.323	0.318	0.351
G1	0.259	0.256	0.326	0.337	0.176	0.208	0.204	0.375	0.420	0.398	0.338	0.353	0.314	0.316	0.348
G2	0.211	0.255	0.310	0.309	0.201	0.236	0.218	0.308	0.403	0.352	0.397	0.423	0.418	0.340	0.377
G3	0.264	0.295	0.383	0.343	0.215	0.263	0.226	0.370	0.449	0.398	0.292	0.337	0.337	0.359	0.394
H1	0.189	0.274	0.328	0.222	0.194	0.316	0.305	0.409	0.435	0.416	0.219	0.258	0.246	0.338	0.313
H3	0.217	0.262	0.336	0.295	0.199	0.279	0.256	0.389	0.446	0.390	0.251	0.307	0.327	0.328	0.360
H4	0.174	0.260	0.329	0.280	0.193	0.252	0.221	0.472	0.493	0.467	0.234	0.274	0.275	0.320	0.341
H7	0.344	0.345	0.406	0.382	0.177	0.307	0.282	0.343	0.444	0.484	0.402	0.415	0.409	0.350	0.434
H8	0.431	0.432	0.479	0.458	0.125	0.288	0.283	0.271	0.401	0.428	0.447	0.465	0.479	0.345	0.418
I4	0.215	0.334	0.382	0.337	0.105	0.262	0.215	0.463	0.514	0.488	0.300	0.301	0.350	0.335	0.356
I5	0.154	0.252	0.325	0.275	0.147	0.223	0.236	0.491	0.513	0.473	0.240	0.281	0.305	0.344	0.384
I6	0.109	0.215	0.277	0.204	0.181	0.219	0.230	0.502	0.515	0.456	0.213	0.242	0.269	0.343	0.365

Table 6.8 Correlation Matrix (Continued)

	F1	F2	F3	G1	G2	G3	H1	H3	H4	H7	H8	I4	I5	I6
F1	1.000													
F2	0.710	1.000												
F3	0.670	0.850	1.000											
G1	0.455	0.508	0.489	1.000										
G2	0.443	0.515	0.471	0.652	1.000									
G3	0.483	0.525	0.501	0.685	0.600	1.000								
H1	0.425	0.371	0.362	0.334	0.270	0.426	1.000							
H3	0.360	0.376	0.388	0.337	0.311	0.490	0.597	1.000						
H4	0.408	0.434	0.406	0.344	0.267	0.507	0.652	0.718	1.000					
H7	0.406	0.423	0.412	0.400	0.391	0.395	0.378	0.377	0.446	1.000				
H8	0.251	0.278	0.270	0.325	0.377	0.328	0.237	0.265	0.269	0.667	1.000			
I4	0.358	0.411	0.398	0.446	0.349	0.462	0.502	0.518	0.562	0.405	0.337	1.000		
I5	0.368	0.400	0.388	0.433	0.351	0.430	0.507	0.443	0.519	0.382	0.331	0.736	1.000	
I6	0.359	0.339	0.362	0.377	0.356	0.429	0.530	0.489	0.533	0.367	0.268	0.655	0.801	1.000

Table 6.9 Inter-Construct Correlations

	Participation	Software Needs	Professional Benefits	Enjoyment	Identification	Obligation	Shared Values	Shared Goals	Cognitive Trust	Affective Trust	Leader Support
Participation	1										
Software Needs	0.18	1									
Professional Benefits	0.49	0.22	1								
Enjoyment	0.48	0.14	0.43	1							
Identification	0.66	0.21	0.50	0.54	1						
Obligation	0.55	0.20	0.45	0.49	0.62	1					
Shared Values	0.34	0.19	0.31	0.50	0.46	0.47	1				
Shared Goals	0.44	0.24	0.30	0.58	0.54	0.56	0.68	1			
Cognitive Trust	0.39	0.24	0.35	0.63	0.40	0.51	0.53	0.56	1		
Affective Trust	0.59	0.19	0.38	0.58	0.66	0.60	0.47	0.56	0.50	1	
Leader Support	0.36	0.17	0.28	0.66	0.39	0.52	0.48	0.58	0.71	0.48	1

6.7 Test of the Hypotheses – the Structural Model

Based on the measurement model, the structural model is analyzed to test the hypotheses or paths in the research model. The structural model is analyzed using SAS PROC CALIS procedure.

The structural model fits adequately with the data, with RMSEA equal 0.0506 (which is smaller than 0.08, and approaches 0.05). Other fit indices include chi-square = 696.03 (d.f.=336, $p<0.001$), NFI = 0.9170, NNFI = 0.9455, GFI = 0.8980, and CFI = 0.9549. Assessing the results in terms of paths, proposed hypotheses are supported as follows. The path from identification to participation (t-value = 6.71), the path from affective trust to enjoyment (t-value = 4.90), the path from leader support to enjoyment (t-value = 4.41), the path from affective trust to identification (t-value = 7.50), and the path from affective trust to obligation (t-value = 5.77) are significant at the level of 0.001. The path from professional benefits to participation (t-value = 2.99), the path from obligation to participation (t-value = 2.65), the path from cognitive trust to enjoyment (t-value = 2.87), the part from shared goals to identification (t-value = 2.16), and the path from shared goals to obligation (t-value = 1.78) are significant at the level of 0.05. The path from enjoyment to participation (t-value = 1.43), and the path from leader from obligation (t-value = 1.37) are weakly supported at the level of 0.1.

Some hypotheses are not supported. They include the path from personal software needs to participation (t-value = 0.03), the path from shared value to enjoyment (t-value = 0.82), the path from shared goals to enjoyment (t-value = 1.27), the path from shared value to identification (t-value = 0.77), the path from cognitive trust to identification (t-value = 0.09), the path from leader support to identification (t-value = -0.86), the path

from shared value to obligation (t-value = 0.55), and the path from cognitive trust to obligation (t-value = 1.14).

Table 6.10 Standardized Path Estimates for Structural Model

Path	Estimate	t-value	p-value
Software Needs → Participation	0.0053	0.03	n.s.
Professional Benefits → Participation	0.1919	2.99	<0.05
Enjoyment → Participation	0.0857	1.43	<0.1
Identification → Participation	0.4378	6.71	<0.001
Obligation → Participation	0.1730	2.65	<0.05
Shared Values → Enjoyment	0.0489	0.82	n.s.
Shared Goals → Enjoyment	0.0902	1.27	n.s.
Cognitive Trust → Enjoyment	0.1964	2.87	<0.05
Affective Trust → Enjoyment	0.2983	4.90	<0.001
Leader Support → Enjoyment	0.2963	4.41	<0.001
Shared Values → Identification	0.0510	0.77	n.s.
Shared Goals → Identification	0.1738	2.16	<0.05
Cognitive Trust → Identification	0.0067	0.09	n.s.
Affective Trust → Identification	0.6408	7.50	<0.001
Leader Support → Identification	-0.0628	-0.86	n.s.
Shared Values → Obligation	0.0392	0.55	n.s.
Shared Goals → Obligation	0.1540	1.78	<0.05
Cognitive Trust → Obligation	0.0930	1.14	n.s.
Affective Trust → Obligation	0.4624	5.77	<0.001
Leader Support → Obligation	0.1072	1.37	<0.1

The model explains 49 percent of the variance in Participation, 58 percent of the variance in Enjoyment, 57 percent of the variance in Identification, and 52 percent of the variance in Obligation.

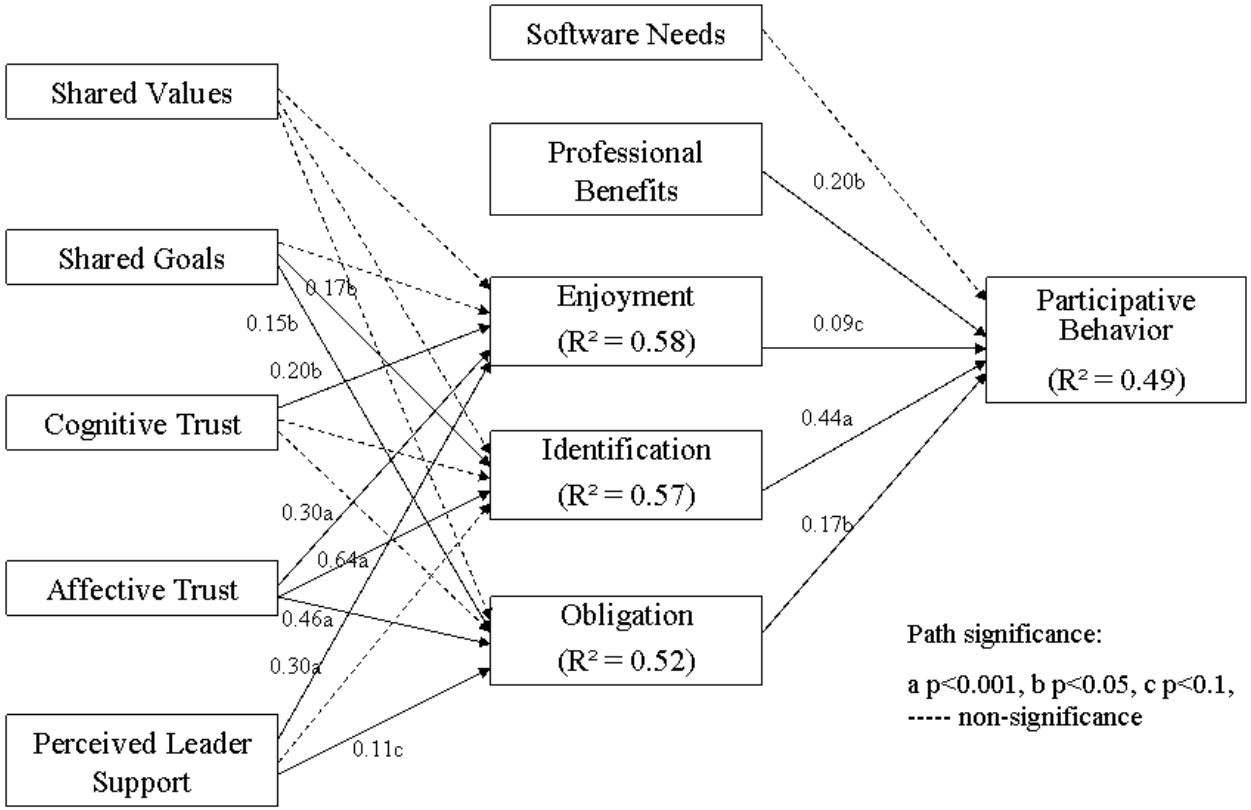

Figure 6.1 Hypotheses Testing of Structural Model

6.8 Refinement of the Structural Model

The RMSEA for the structural model is 0.0506, and the GFI for the structural model is 0.8980, which is a little lower than the cut-off value (0.90). It is possible to refine the model for better fit. Although there are many alternative models that may display good fit, the refinement must be based on theories, rather than creating any further causal relationships between the latent constructs. Joreskog and Sorbom (1993) have proposed several general guidelines for model refinement: (1) fixed parameters with large modification indices should be relaxed, (2) estimated parameters whose t-values are not significant should be fixed at zero, (3) estimated parameters whose signs are not supported by theory should be considered for fixing at zero, and (4) modifications should be made in steps, with one parameter fixed at a time, and the results carefully examined.

The results of the structural model (shown in Figure 6.1) show that shared values and software needs have no significant relationship with other factors. After deleting these two factors, the structural model is improved. The indices include chi-square 559.56 (df = 249, $p<0.001$), GFI = 0.9026, AGFI = 0.8729, RMR = 0.0501, RMSEA = 0.0546, CFI = 0.9546, NFI = 0.9216, NNFI = 0.9453. All the indices are above the cut-off values, which indicates a good fit for the data.

Table 6.11 Standardized Path Estimates for Structural Model Modified

Path	Estimate	t-value	p-value
Professional Benefits → Participation	0.1921	4.16	<0.001
Enjoyment → Participation	0.0845	1.56	<0.1
Identification → Participation	0.4400	6.88	<0.001

Obligation → Participation	0.1749	2.82	<0.05
Shared Goals → Enjoyment	0.1211	2.01	<0.05
Cognitive Trust → Enjoyment	0.2093	3.10	<0.05
Affective Trust → Enjoyment	0.3011	4.96	<0.001
Leader Support → Enjoyment	0.2903	4.33	<0.001
Shared Goals → Identification	0.2017	2.95	<0.05
Cognitive Trust → Identification	0.0187	0.25	n.s.
Affective Trust → Identification	0.6474	7.56	<0.001
Leader Support → Identification	-0.0661	-0.90	n.s.
Shared Goals → Obligation	0.1763	2.40	<0.05
Cognitive Trust → Obligation	0.1024	1.28	n.s.
Affective Trust → Obligation	0.4661	5.82	<0.001
Leader Support → Obligation	0.1047	1.33	<0.1

In the modified structural model, thirteen paths are supported, among which the paths between professional benefits and participation, between identification and participation, between affective trust and enjoyment, between leader support and enjoyment, between affective trust and identification, between affective trust and obligation are significant at the level of 0.001. The paths between obligation and participation, between shared goals and enjoyment, between cognitive trust and enjoyment, between shared goals and identification, and between shared goals and obligation are significant at the level of 0.05. The paths between enjoyment and participation and between leader support and obligation are weakly supported at the level of 0.1. Three paths are not supported by the data, which are the paths between cognitive trust and identification, between leader support and identification, and between cognitive trust and obligation.

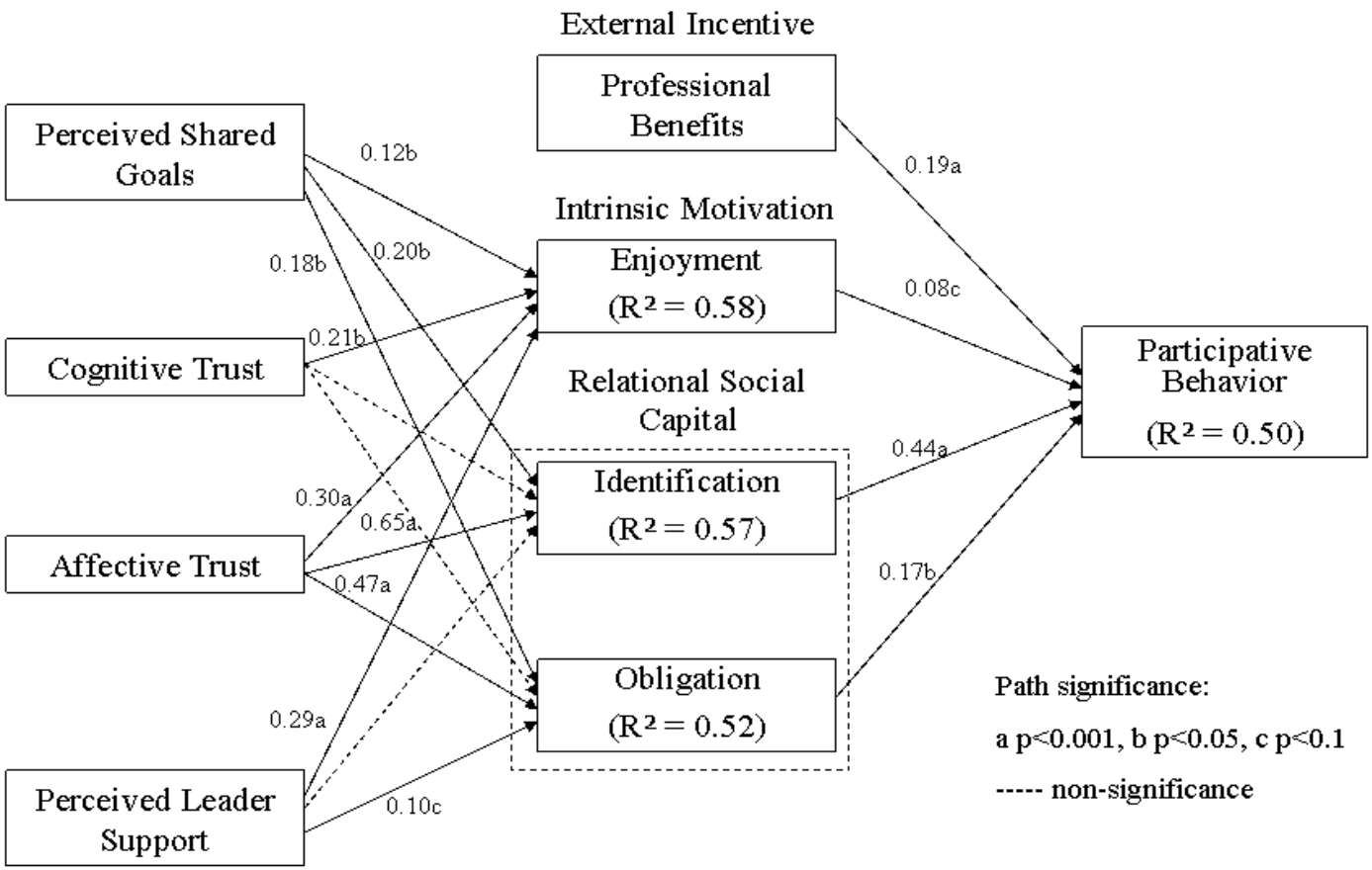

Figure 6.2 Hypotheses Testing of Structural Model (Modified)

6.9 Supplemental Study

Structural equation modeling has some limitations as data analysis method. For example, it can not take consideration the problem of "repeated measures", which refers to the dependence among the observations in the same cluster. In this study, the 420 observations are from 251 open source projects, so the multiple observations from the same project are supposed to be dependent. To solve the problem, a supplemental study was conducted to the SEM analysis.

In the supplemental study, ten data sets are created from the original data set which contains 420 observations by using stratified random sampling, which means one observation is randomly selected from each project, so there is no dependence among the observations in the new data sets. Then each of the new data sets is fitted into the structural model as showed in Figure 6.2, to see if the results are consistent with the results from SEM conducted on the 420 observations, and if the results using different data sets are consistent with each other.

The results of the supplemental study are showed in Appendix E.

The results from the ten new data sets are mostly consistent with the results with the original data set described above, and they are mostly consistent with each other. The links which are very significant with the original data set, including the links between professional benefits and participation, between identification and participation, between obligation and participation, between affective trust and enjoyment, between leader support and enjoyment, between affective trust and identification, between shared goals and obligation, between affective trust and obligation, are supported with all the ten new data sets. Some links which are significant with the original date set, including the links

between enjoyment and participation, between shared goals and enjoyment, between cognitive trust and enjoyment, between shared goals and identification, between leader support and obligation, are supported with some of the new data sets. The links which are not supported with the original data set, including the links between cognitive trust and identification, between cognitive trust and obligation, between leader support and identification, are rejected with all the new data sets.

The supplemental study indicates that professional benefits, identification, obligation are the major motivational factors for participation, affective trust, shared goals, and leader support are some major antecedent factors to identification or obligation.

6.10 Discussion

The original structural model shows no significant relationship between personal software needs and the level of participation. This can be interpreted as that volunteer's personal need for the software being developed is important for him to join the project, however, since most participants are attracted to a certain project because they have personal needs for the software, personal software needs does not account for the difference in their level of participation in the project much.

The original structural model shows no significant relationship between shared values and enjoyment, identification or obligation. This can be interpreted as that there is no much distinction between shared values and shared goals from the view of the voluntary developers. The commonality in values is often perceived through the commonality in goals by the participants.

In the modified structural model, identification has greatest impact on the developer's participative activities. This is interpreted as that open source software development requires initiatives and investment of time and energy, so identification plays an important role to promote a developer's voluntary input into the project. Professional benefits and obligation also have some impact on the participation level, while enjoyment is not very significant in accounting for the participation level from a developer. Most people become a member of an open source project because it is fun, however, the software development process is often a task which requires much effort, and sometimes some work is boring or mundane, so enjoyment does not explain the difference in participation level much.

Perceived shared goals has significant impact on enjoyment, identification and obligation. Cognitive trust has significant impact on enjoyment, but no significant impact on identification or obligation. Cognitive trust is mainly between the developer and other members, and is not generalized as a feeling or relationship to the project or community as a whole. However, affective trust has great impact on enjoyment, identification and obligation, which implies that the relationship building among members is quite important, and it has great influence on the developer's emotion to the project. This is quite consistent with the community-based nature of open source project, since that emotional relationship among members serves as glue which holds a community together.

Perceived leader support has significant impact on enjoyment and obligation, but no significant impact on identification. This can be interpreted as that leader support mostly promotes the members' participation and loyalty through reciprocity.

From the data analysis, we see that the social relational factors play a very important role in an open source community by promoting the developers' voluntary participation. And the relationship between the voluntary developers and the project can be enhanced through aggregation of members with common goals, through formation of the trusting relationships among members in the same project, and through some effective leadership. Since the open source software development is conducted by virtual communities, and there is no formal control in the process of open source software development, the social relational factors which can promote the volunteers' self-motivation are very important, and should be much emphasized in the management of open source projects.

CHAPTER VII

DISCUSSION AND CONCLUSIONS

Open source software development is different from traditional software development in that it is based on online community and the developers are volunteers which do not have formal affiliation to the project. The success of an open source project depends on the contribution or participation from the voluntary developers. How to promote developers' voluntary participation is critical to the success of the project and the final outcome of the software development. People participate in open source projects to obtain programming skills and reputation which would be helpful to their professional status, or to pursue enjoyment through communication and association with others of common interests. It is difficult to control developers' activities by formal mechanism due to the community-based nature of open source project. However, the developers' contribution can be promoted through building of community with high quality. This research finds that a voluntary developer's contribution to or involvement into an open source project can be promoted by enhancing his identification with, obligation to, or enjoyment with the community. And the identification, obligation and enjoyment are influenced by the social relationships among the members in the same community and the effectiveness of the leadership.

7.1 Implications for Theory and Practice of Open Source Software Development

Open source software is imposing some great impacts on the society and the software industry. Further and better understanding of open source software and projects

is very important for the management of open source software development. Currently, the research on open source software is focused on revealing the motivations of volunteers for open source project participation at general levels. Very few research investigates open source software development from the community perspectives. To provide guidance for project management, this research investigates the community factors which influence the developers' participation activities. It is found that a member's participation can be promoted through his identification with or obligation to the project community. So the social relational factors have complementary explanation power for open source participation in addition to the extrinsic incentives and intrinsic motivations which have been found in prior studies. The social relational factors are even more important or critical in the open source context due to the community-based nature. This research provides a better understanding of the motivations for open source participation, and helps to make a better and more comprehensive theory in this field.

This research has some practical implications for open source project management. Open source software development takes an online community as its organizational form. The development process is regarded as self-organized since there is no formal control to the relationship between the voluntary developers and the projects. How to lead or manage the project is the concern of most project leaders. This research reveals that the voluntary participations' activities can be influenced through online community factors. And the members' commitment to the project can be promoted through enhancing the relationship among members, through effective leadership, and through community building. So, an open source project can be "managed" although it is based on a community. The research found that a voluntary developer's identification

with, obligation to, and enjoyment with an open source project can be influenced by the shared goals, trusting relationships in the community and the caring and help from the leader(s). So, open source project leaders can play important role in making successful projects through promotion of goal congruence, appropriate member selection, relationship building among members, and by providing assistance in task completion and caring in mind.

The findings of this study are consistent with the theories and literature of project management. It shows that project leaders can promote developers' participation through caring and emotional supports, this is consistent with Maslow's hierarchy of needs, which indicates that upper level needs like needs for social, esteem and self-actualization motivate human behaviors. The findings are also consistent with Herzberg's motivational factors in that recognition, work enjoyment, chance of professional growth and learning are important factors to motivate open source contribution. The results of this study confirm McGregor's Theory Y and Ouchi's Theory Z. So this study contributes to project management research by extending the theories of project management to the open source context, which is relatively new phenomenon.

Voluntary participation is the most critical factor to the success of an open source project. This research enriches the literature of open source software by introducing social relational factors into the study of open source software development and investigating their effects in the context. This research also offers answer to some questions raised in prior studies, for example, how to sustain volunteer's contribution to a certain project? What role can project leader plays in open source software development (von Hippel and Krogh 2003)? The results of the research indicate that quality of

community is very important to the success of an open source project since it has great impact on the behavior of participants.

7.2 Implications for Theory and Practice of Virtual Communities

Open source software development takes virtual community as its organizational form, and open source community is often considered to be a special type of online community. The major characteristic of virtual community is that it is based on the Internet and the participation is voluntary. Social relational capital, such as identification and trust, has been demonstrated to be very important in physical collaboration environment. How to generate relational capital in virtual collaboration is currently attracting much attention from both information systems and organization research. Some studies on virtual team indicate that identification can be formed in virtual teams through communication although there is no face-to-face interaction (e.g. Fiol and O'Connor 2005).

Virtual community is more loosely-structured compared to virtual team since the participation is voluntary and there is no formal affiliation between the members and the community. Social relational factors, like identification and obligation, are more important for virtual community due to the lack of formal control mechanism. Wasko et al. (2004) proposed that identification and obligation can be generated from exchange in the virtual community, and they have impact on the person's knowledge contribution. This research empirically confirms this idea by investigating social relational factors and their impacts in open source communities. The research also confirms that extrinsic incentives (e.g. reputation gaining) and intrinsic motivation (e.g. enjoyment) impact

voluntary participation in virtual communities, which is consistent with the findings of prior studies on virtual community (e.g. Wasko et al. 2005). The research finds that in open source context, interpersonal trust and similarity among members are very important to attract and retain individuals to an online community, and promote their participation. This is consistent with the findings of prior studies of virtual communities (e.g. Geng et al. 2004; Lou and Luo 2000; Blanchard and Markus 2004). So, this study extends some theory or findings of virtual community to the open source context, which is a special type and has some unique characteristics.

The research has some practical implications for virtual community management. Virtual community is often regarded as self-organized structure, the survival and popularity seems to completely depend on the participants' self-motivation and willingness. Thompson (2005) suggests that success of a virtual community may be obtained through "interference" or support from organizational managers. This research confirms this view in open source context by concluding that participants' contribution and involvement can be managed through enhancing the quality of the virtual community. As a type of online community, open source community is special in that it has software product output, and the quality of product depends on the process of development in the community. The research provides some guidance on how to manage the development process so as to obtain effectiveness, efficiency and high quality in open source software development.

7.3 Implications for Theory and Practice of Organizational Behavior

Open source community is regarded as a new organizational form for knowledge creation (Lee and Cole 2003). It has some special traits that are significantly different from traditional firm-based organizations. Knowledge management is a very important aspect in organization studies since knowledge is a critical competitive advantage for a company. The research of entrepreneurship indicates that leadership, social capital and citizenship behaviors are critical to employees' voluntary knowledge contribution. This research extends the theory to the new "C-firm" organization of open source community, and finds that such factors also play an important role for voluntary knowledge contribution in the open source context.

Knowledge management has become an important area for research in information systems since information technologies are used to support knowledge creation, sharing and storage. Some studies on knowledge management find that anticipated rewards, enjoyment and organizational identification and reciprocity have influence on individuals' knowledge contribution or usage of knowledge management systems in physical organizational context (e.g. Bock et al. 2005; Kankanhalli et al. 2005). This research confirms the findings in the context of open source software development by suggesting that these factors are important for participation in the open source projects.

The research also has some implications for project management. Project management is considered to be very important in information systems research since it is critical to the timely completion and quality of final product. It has been demonstrated that multiple control modes are used in information systems development projects to

align the individual behaviors with the project objectives (Kirsch 1997). However, in the open source community where there is no formal affiliation or formal control mechanism, clanship control based on community-building and self-control based on individuals' self-motivation and self-esteem are more important for effective project management. So, the project leadership in open source projects should be emphasized on community-building and member selection.

7.4 Limitations

There are several limitations to the present study. The first is the external validity due to the specially defined and selected samples. To assess the external validity of a study, both the respondents and the setting in which the study is conduced should be evaluated. The setting for the study was Sourceforge.net, the largest Website for open source projects, and the respondents were voluntary developers in some ongoing projects. The generalizability of the findings may be limited. Although Sourceforge.net has the largest number of open source projects, some big projects, like Linux and Mozilla, have their own Websites, and are not contained on Sourceforge.net, so they are not included in this study. In addition, in order to get more response, only ongoing projects are considered in this study, so the projects on Sourceforge.net are not randomly sampled. And the respondents for the survey are not randomly sampled from the population of open source participants. In addition, the survey responses from the participants in the selected projects are purely voluntary, so there may exist response bias in the data collection. This study focuses on the virtual community factors and their impacts, the projects on Sourceforge.net are not different from others in the aspect of community-

based organization form. In addition, the ongoing projects selected for the study covers a wide range of topics, license types and development stages, which enhances the generalizability of the findings. The research is at the individual level, and open source project participation is generally under the individual's absolute control, so the sampling bias at the project level should not have much influence on the results at the individual level.

The second limitation is the use of a single source for respondents' information. All the data for testing the research model were collected from respondents' subjective measures. Hence, the study depended on each respondent by assuming that he is reliable in providing answers reflecting perceptions of the constructs in the model. The potential problems with the survey method could have affected the quality of the study. However, the response to the survey is completely voluntary and anonymous, and the respondents are real developers in open source projects, so the problems with survey method are believed to be avoided as much as possible.

The third limitation is due to the nature of structural equation modeling. Structural equation modeling is a data analysis method with much advantage. However, it also has some limitation. It can not handle the problem of "repeated measure" or multi-level data well. In this study, there are 420 responses from 251 different projects, so multiple responses from the same project are supposed to be dependent. Structural equation modeling can not consider such dependence. To solve the problem, a supplementary data analysis was conducted, and the results are consistent with the results by structural equation modeling.

The fourth limitation is due to the nature of a cross-sectional study. To explore the causality of constructs in a model, longitudinal studies provide strong methodological support. A longitudinal design would perhaps be a better method to test the research model in the study. Due to the difficulty of getting observations over a period of time, this study uses cross-sectional method by getting observations at one time points from many respondents which are expected to have much variance in perception, beliefs and experience in open source project participation. As the data are cross-sectional and not longitudinal, the posited causal relationships (although firmly based in generally accepted theories) could only be inferred rather than proven.

7.5 Future Work

The research model for open source project participation in this dissertation is one of the earliest in information systems research. Therefore, there are many conceptual and empirical considerations that might be improved in future studies. The first is to test the research model using objective data. Currently, there are a large quantity of open source projects on the Internet, and much objective information about projects and developers can be obtained from the project web pages or through content analyze the mailing lists, discussion forum and code repository. So, a further study at project level with objective data would complement this research and make the current research findings more convincing.

The second is to consider the influence of project development phase, and investigates the dynamics of the constructs and evolution of their impacts over different project phases. Based on prior organizational studies, the control system and the inter-

personal relationships evolve over time with the maturity of the organization. It would provide a better understanding of voluntary open source participation to investigate the dynamics of the constructs and the difference of their roles in various project phases. This would provide advice to project leaders on how to manage the development process at various stages.

The third is to extend the research by including more research factors. This dissertation chose external incentive, intrinsic motivation and relational social capital as the major influential factors for open source participation. In fact, there are some other theories which can be applied to the open source context. For example, social influence has been studied for knowledge contribution and voluntary adoption in some physical organizational contexts. It can be introduced into the study of open source software development to investigate the influence of peer-pressure, morale and social atmosphere in an open source community. Theory of psychological contract has been used to understand the relationship between employee and company, or the relationship between strategic alliances. It can be adopted in the open source context to understand the expectation of voluntary developers for the community or project, so as to provide advice on how to manage their activities and loyalty to the community. Some constructs in the research model can be studied in more depth. For example, this dissertation finds that leader support plays an important role in the generation of enjoyment and obligation by the developers. The leader's role in open source projects can be studied in more details, for example, there are relations-oriented, task-oriented and participative leadership style, what type of leadership is the most effective in open source context, what specific support should the project leaders offer to the voluntary developers.

The fourth is to consider the influence of personality or traits of participants in the open source context. Participants' self-motivation and self-control is very important in open source projects due to its community-based nature. The motivational factors like identification and obligation are often related to the person's personality or trait characteristics. Understanding such relationships is very helpful for better member selection, and would provide guidance for the management of open source projects.

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Appendix A: Email sent to Open Source Software Developers to Invite for Participation in the Survey

Dear OSS developer,

I am a doctoral student in management information systems at Texas Tech University. For my dissertation research I am studying open source software development participation activities. You could make an important contribution to this research by completing a questionnaire at http://ta.ba.ttu.edu/bxu/oss-survey.asp. Please take a few minutes to answer the questions. The survey is just for research purposes and your response will remain anonymous. Your assistance is highly appreciated.

Sincerely,

Bo Xu
Rawls College of Business Administration
Texas Tech University
Lubbock, Texas

Appendix B: Open Source Software Participation Survey

We are interested in people's feelings and participation in open source software projects. Your assistance in answering this questionnaire is appreciated. It should take no more than 10 minutes to complete. Some of the questions may seem repetitive but all have a purpose. All the data will be kept confidential.

Please give the name of the project on Sourceforge.net in which you are a member (If you participate in two or more projects at the time, please choose one of them).

Project Name: FreeImage

Part A

A1. How long have you been in this project?

☐ Less than 6 months ☐ 6-12 months ☐ 1-2 years ☐ 2-3 years ☐ More than 3 years

A2. How many hours/week do you spend on the project?

☐ Less than 1 hour ☐ 2-4 hours ☐ 5-8 hours ☐ 9-20 hours ☐ More than 20 hours

	Strongly Disagree						Strongly Agree
A3. I put much effort into the project.	1	2	3	4	5	6	7
A4. I fully support the project.	1	2	3	4	5	6	7
A5. I make this project a high priority in my life.	1	2	3	4	5	6	7
A6. I frequently contribute my knowledge to the project.	1	2	3	4	5	6	7

Part B

	Strongly Disagree						Strongly Agree
B1. I personally need the software being developed.	1	2	3	4	5	6	7
B2. I learn knowledge or skills by participating in the project.	1	2	3	4	5	6	7
B3. I earn respect from others by participating in the project.	1	2	3	4	5	6	7
B4. I feel that participation in the project improves my status in the profession.	1	2	3	4	5	6	7
B5. Participation in the project improves my reputation in the profession.	1	2	3	4	5	6	7

Part C

	Strongly Disagree						Strongly Agree
C1.The actual process of participating in the project is pleasant.	1	2	3	4	5	6	7
C2. I have fun being a member of the project.	1	2	3	4	5	6	7
C3. Participation in the project bores me.	1	2	3	4	5	6	7
C4. Participation in the project provides me with a lot of enjoyment.	1	2	3	4	5	6	7

Part D

	Strongly Disagree						Strongly Agree
D1.When I talk about the project, I usually say 'we' rather than 'they'.	1	2	3	4	5	6	7
D2. The project's successes are my successes.	1	2	3	4	5	6	7
D3. I am very interested in what others think about the project.	1	2	3	4	5	6	7
D4. When someone praises the project, it feels like a personal compliment.	1	2	3	4	5	6	7
D5. When someone criticizes the project, it feels like a personal insult.	1	2	3	4	5	6	7

Part E

	Strongly Disagree						Strongly Agree
E1.I feel a sense of obligation to continue participating in this project.	1	2	3	4	5	6	7
E2. I believe that loyalty to this project is important.	1	2	3	4	5	6	7
E3. It would be wrong for me to stop being a member in the project.	1	2	3	4	5	6	7
E4. Jumping from this project to others does not seem right to me.	1	2	3	4	5	6	7

Part F

	Strongly Disagree						Strongly Agree
F1.Others in the project have the same values as I do with regard to open source software.	1	2	3	4	5	6	7
F2. In general, my values and the values held by the project are very similar.	1	2	3	4	5	6	7
F3. I believe in the same values held and promoted by the project.	1	2	3	4	5	6	7

Part G

	Strongly Disagree						Strongly Agree
G1.My goals for this project are shared by others.	1	2	3	4	5	6	7
G2. My partners have similar motives for conducting this project.	1	2	3	4	5	6	7
G3. I have compatible goals for the project with others.	1	2	3	4	5	6	7
G4. My partners and I have different goals for the project.	1	2	3	4	5	6	7
G5. My partners support my objectives.	1	2	3	4	5	6	7

Part H

	Strongly Disagree						Strongly Agree
H1.The members in the project approach their jobs with professionalism and dedication.	1	2	3	4	5	6	7
H2. I can rely on other members not to make my job more difficult by careless work.	1	2	3	4	5	6	7
H3. Other members in the project can be respected as coworkers.	1	2	3	4	5	6	7
H4. Other members with whom I must interact are considered to be trustworthy.	1	2	3	4	5	6	7
H5. I can freely share ideas, feelings and hopes with others in the project.	1	2	3	4	5	6	7
H6. I can talk freely to others in the project about difficulties I am having and know they will want to listen.	1	2	3	4	5	6	7
H7. I would feel a sense of loss if one of us was transferred and we could no longer work together.	1	2	3	4	5	6	7
H8. I would have to say I have made considerable emotional investment in working relationships with others in the project.	1	2	3	4	5	6	7

Part I

	Strongly Disagree						Strongly Agree
I1.The leader(s) show very little concern for me.	1	2	3	4	5	6	7
I2. The leader(s) really care about my well-being.	1	2	3	4	5	6	7
I3. The leader(s) strongly consider my goals and values.	1	2	3	4	5	6	7

I4. The leader(s) care about my opinions.	1	2	3	4	5	6	7
I5. The leader(s) is willing to help me perform my tasks to the best of my ability.	1	2	3	4	5	6	7
I6. Help is available from the leader(s) when I have a problem.	1	2	3	4	5	6	7
I7. The leader(s) recognize my potential.	1	2	3	4	5	6	7

Background Information

1. Gender ☐ Male ☐ Female

2. Age ☐ under 20 ☐ 20 - 29 ☐ 30 - 39 ☐ 40 - 49 ◉ over 50

Appendix C: List of Open Source Projects

Project Name	Topic Type	Registration Date	License Type	Developer	Status	Response
.NetTiers: OR mapper codesmith template	Software development	9/8/2004	GNU Library or Lesser General Public License (LGPL)	11	beta	1
]project-open[	Business applications	7/23/2003	GNU General Public License (GPL)	14	production	2
Adium	Communications	11/19/2002	GNU General Public License (GPL)	22	production	6
Alfresco Content Management	Business applications	7/8/2005	Mozilla Public License 1.1 (MPL 1.1)	12	production	2
Allegro game programming library	Games/Entertainment	5/13/2000	Other/Proprietary License	19	mature	1
Ambulant	Multimedia	10/1/2003	GNU General Public License (GPL)	8	production	1
AMFPHP (Flash Remoting for PHP)	Internet	1/26/2003	GNU General Public License (GPL)	12	beta	1
AMIS	Other	7/31/2003	GNU Library or Lesser General Public License (LGPL)	6	production	2
AMSN (Alvaro's Messenger)	Communications	5/22/2002	GNU General Public License (GPL)	18	beta	1
AMX Mod X	Games/Entertainment	1/25/2004	GNU General Public License (GPL)	6	production	2
AndroMDA	Software development	2/2/2003	BSD License	10	production	1
Anjuta C/C++ IDE	Software development	11/6/2000	GNU General Public License (GPL)	14	beta	1
Anope IRC Services	Internet	11/3/2003	GNU General Public License (GPL)	7	production	1
APLAWS	Business applications	1/14/2003	GNU Library or Lesser General Public License (LGPL)	13	production	1
APS/NWNX	Database	3/22/2003	GNU General Public License (GPL)	4	beta	1
Aqsis Renderer	Multimedia	4/14/2001	GNU General Public License (GPL)	23	beta	2
Armagetron Advanced	Games/Entertainment	6/2/2004	GNU General Public License (GPL)	14	production	1
Artificial Knowledge Interface for Reasoning Applications	Software development	10/21/2001	Other/Proprietary License	16	pre-alpha	1
ATLAS (Automatically Tuned Linear Algebra Software)	Scientific/Engineering	3/26/2001	BSD License	5	mature	1
ATMEL Linux PCI PCMCIA USB Drivers	Software development	7/30/2002	GNU General Public License (GPL)	4	production	1
Audacity	Multimedia	5/28/2000	GNU General Public License (GPL)	31	production	2
BASE(Basic Analysis and SecurityEngine)	Internet	2/27/2004	GNU General Public License (GPL)	5	production	1
BibDesk	Business applications	9/1/2002	BSD License	10	beta	1
Big Sister	Systems Administration	11/4/2000	GNU General Public License (GPL)	14	beta	1

bitweaver	Software development	6/13/2005	GNU Library or Lesser General Public License (LGPL)	45	production	4
Boa Constructor - wxPython GUI Builder	Software development	1/27/2000	GNU General Public License (GPL)	8	alpha	2
Boost C++ Libraries	Software development	6/29/2000	Other/Proprietary License	106	beta	10
Boson	Games/Entertainment	11/21/2000	GNU General Public License (GPL)	10	alpha	1
BRL-CAD	Multimedia	3/23/2004	BSD License	19	planning	2
Btech-Online Battletech MUX	Games/Entertainment	1/5/2005	Artistic License	16	beta	2
Bugzilla Test Runner	Software development	11/22/2003	Mozilla Public License 1.1 (MPL 1.1)	4	production	1
ByteHoard	Internet	9/14/2003	GNU General Public License (GPL)	8	beta	1
CARE2X php Integ Hospital Info System	Scientific/Engineering	5/19/2002	GNU General Public License (GPL)	105	beta	1
Checkstyle	Software development	6/20/2001	GNU Library or Lesser General Public License (LGPL)	5	mature	1
Chicken of the VNC	Internet	10/8/2002	GNU General Public License (GPL)	6	production	1
ChurchInfo	Database	8/20/2004	GNU General Public License (GPL)	9	production	2
Cisco-centric Open Source Initiative	systems Administration	4/16/2001	BSD License	48	beta	1
Clam AntiVirus	Internet	7/26/2003	GNU General Public License (GPL)	12	beta	1
ClamWin Free Antivirus	Internet	3/25/2004	GNU General Public License (GPL)	8	beta	2
CMU Sphinx	Multimedia	1/27/2000	BSD License	29	pre-alpha	2
Cobertura	Software development	2/4/2005	GNU General Public License (GPL)	5	production	1
Code::Blocks	Software development	12/20/2004	GNU General Public License (GPL)	12	beta	2
Community Mapbuilder	Internet	9/7/2001	GNU Library or Lesser General Public License (LGPL)	11	beta	1
Conky	Systems Administration	7/16/2005	BSD License	10	production	1
Crazy Eddie's GUI System	Software development	10/30/2003	GNU Library or Lesser General Public License (LGPL)	8	beta	1
Danger from the Deep	Games/Entertainment	1/10/2003	GNU General Public License (GPL)	8	alpha	1
Dark Oberon	Games/Entertainment	11/12/2002	GNU General Public License (GPL)	4	beta	1
Dave's Quick Search Deskbar	Desktop Environment	12/14/2001	GNU General Public License (GPL)	19	production	2
DBE Studio	Software development	7/15/2005	Eclipse Public License	15	alpha	1
devkitPro	Software development	7/14/2004	GNU General Public License (GPL)	23	production	1
Distributed Generic Information Retrieval (DiGIR)	Database	10/19/2001		31	beta	1
DOSEMU for Linux	Systems Administration	3/25/2002	GNU General Public License (GPL)	5	beta	1

Dropline GNOME	Desktop Environment	9/9/2002	BSD License	12	production	6
DrPython	Software development	6/8/2003	GNU General Public License (GPL)	11	production	1
Druid, The Database Manager	Database	11/21/2000	GNU General Public License (GPL)	11	production	1
DScaler Deinterlacer/Scaler	Multimedia	6/26/2000	GNU General Public License (GPL)	32	production	1
EasyH10	Multimedia	5/12/2005	GNU General Public License (GPL)	4	beta	1
EasyMOD	Communications	4/20/2005	GNU General Public License (GPL)	8	beta	2
eGroupWare: Enterprise Collaboration	Communications	4/13/2003	GNU General Public License (GPL)	45	production	1
eLML - eLesson Markup Language	Education	11/2/2004	GNU General Public License (GPL)	19	beta	2
Enlightenment	Desktop Environment	11/3/1999	BSD License	70	alpha	6
eXist	Database	1/5/2001	GNU Library or Lesser General Public License (LGPL)	23	beta	2
FBIde	Software development	4/6/2005	GNU General Public License (GPL)	6	beta	1
Finance::Quote	Internet	4/1/2000	GNU General Public License (GPL)	10	production	1
Fink	Systems Administration	12/27/2000	GNU General Public License (GPL)	84	beta	5
FlameRobin	Database	11/17/2004	Other/Proprietary License	6	alpha	2
floAt's Mobile Agent	Communications	1/9/2003	GNU General Public License (GPL)	29	beta	1
FreeGuide TV Guide	Games/Entertainment	9/8/2001	GNU General Public License (GPL)	11	alpha	1
FreeImage	Multimedia	9/16/2000	GNU General Public License (GPL)	7	production	2
FreeMarker	Software development	12/16/1999	BSD License	9	production	1
FreePOPs	Internet	3/28/2004	GNU General Public License (GPL)	11	beta	1
Freevo - Home Theatre PC Platform	Multimedia	2/13/2002	GNU General Public License (GPL)	12	production	2
Gaim	Communications	11/13/1999	GNU General Public License (GPL)	14	production	2
Gallery	Multimedia	6/18/2000	GNU General Public License (GPL)	36	production	2
Ganttproject	Business applications	1/29/2003	GNU General Public License (GPL)	26	production	1
GDPDM	Database	6/30/2005	GNU Library or Lesser General Public License (LGPL)	6		1
Gene Ontology	Scientific/Engineering	10/1/2001	Artistic License	44	beta	2
Generic Model Organism System Database	Database	5/20/2001	Artistic License	82	production	3
GeoTools, the java GIS toolkit	Software development	3/28/2000	GNU Library or Lesser General Public License (LGPL)	49	production	1
GFP	Business applications	4/14/2004	GNU General Public License (GPL)	4	beta	1
Gimp-Print - Top Quality Printer Drivers	systems Administration	1/17/2000	GNU General Public License (GPL)	36	beta	2
GnuWin32	Desktop Environment	3/25/2001	BSD License	5	production	1
Gourmet	Desktop Environment	4/27/2004	GNU General Public License (GPL)	5	beta	2

gPhoto	Multimedia	7/27/2000	GNU General Public License (GPL)	48	production	2
GPU, a Global Processing Unit	Internet	7/18/2002	GNU General Public License (GPL)	31	alpha	1
Group-Office	Business applications	3/14/2003	GNU General Public License (GPL)	9	production	1
GTK+ Gnutella	Communications	4/9/2000	GNU General Public License (GPL)	11	production	1
Guido van Robot	Education	7/10/2003	GNU General Public License (GPL)	6	production	1
guifications	Communications	10/20/2003	GNU General Public License (GPL)	8	production	2
HSQL Database Engine	Database	3/21/2001	BSD License	35	production	1
Inkscape	Desktop Environment	10/26/2003	GNU General Public License (GPL)	57	planning	3
iPodder	Multimedia	9/2/2004	GNU General Public License (GPL)	10	production	1
J2EE Certificate Authority, EJBCA	Internet	11/9/2001	GNU Library or Lesser General Public License (LGPL)	10	production	1
JabRef	Database	10/12/2003	GNU General Public License (GPL)	24	production	1
JasperReports	Software development	9/25/2001	GNU Library or Lesser General Public License (LGPL)	8	production	1
Java Modeling Language (JML)	Software development	10/21/2002	GNU General Public License (GPL)	33	beta	2
Java Object Oriented Neural Engine	Scientific/Engineering	3/12/2001	GNU Library or Lesser General Public License (LGPL)	14	production	1
JavaGroups	Internet	5/25/2000	GNU Library or Lesser General Public License (LGPL)	33	production	2
JBoss.org	Systems Administration	3/15/2001	GNU Library or Lesser General Public License (LGPL)	73	production	2
JFreeReport	Software development	4/18/2002	GNU Library or Lesser General Public License (LGPL)	9	beta	1
jGuard	Internet	4/16/2004	GNU Library or Lesser General Public License (LGPL)	8	beta	1
JiBX - XML Data Binding for Java	Software development	12/13/2002	BSD License	3	beta	1
Jmol	Education	3/25/2001	GNU Library or Lesser General Public License (LGPL)	21	production	1
JMRI Model Railroad Interface	Games/Entertainment	5/6/2001	Artistic License	17	production	1
JSBSim Flight Dynamics Model	Education	1/29/2001	GNU General Public License (GPL)	6	beta	1
JVoiceXML	Multimedia	1/7/2005	GNU Library or Lesser General Public License (LGPL)	9	pre-alpha	1
Jython	Software development	10/13/2000	OSI-Approved Open Source	9	production	2
KeePass Password Safe	Database	11/15/2003	GNU General Public License (GPL)	22	production	1
KMyMoney	Business applications	4/15/2000	GNU General Public License (GPL)	10	beta	1
Koha	Database	12/12/2000	GNU General Public License (GPL)	58	production	4

KoLmafia	Games/Entertainment	12/14/2004	BSD License	12	mature	1
Krusader	Desktop Environment	6/2/2000	GNU General Public License (GPL)	8	production	1
LabPlot	Desktop Environment	9/15/2003	GNU General Public License (GPL)	7	production	1
LAME (Lame Aint an MP3 Encoder)	Multimedia	11/17/1999	GNU General Public License (GPL)	30	production	1
LEAF - Linux Embedded Appliance Firewall	Internet	10/29/2000	GNU General Public License (GPL)	87	production	4
Licq	Communications	11/15/1999	GNU General Public License (GPL)	5	production	1
LifeLines	Communications	12/20/1999	Academic Free License (AFL), MIT License	22	planning	1
Liferay Portal	Internet	3/18/2002	MIT License	63	production	3
LinPHA	Multimedia	10/14/2002	GNU General Public License (GPL)	8	beta	2
lphantGUI	Communications	4/17/2003	GNU General Public License (GPL)	7	beta	1
macam - webcam driver for Mac OS X	Multimedia	1/17/2002	GNU General Public License (GPL)	15	production	1
Magnolia	Software development	7/22/2003	GNU Library or Lesser General Public License (LGPL)	10	production	1
MailWatch for MailScanner	Communications	8/3/2003	GNU General Public License (GPL)	7	production	1
Mantis	Software development	11/18/2000	GNU General Public License (GPL)	18	production	3
Mapbender	Internet	8/23/2003	GNU General Public License (GPL)	11	beta	1
Maven Plugins	Software development	9/2/2002	Apache Software License	39	production	2
Maxima -- GPL CAS based on DOE-MACSYMA	Scientific/Engineering	4/23/2000	GNU General Public License (GPL)	22	production	3
MediaWiki	Database	8/25/2001	GNU General Public License (GPL)	67	production	2
MegaMek	Games/Entertainment	2/19/2002	GNU General Public License (GPL)	28	alpha	2
MekWars	Games/Entertainment	10/18/2004	GNU General Public License (GPL)	8	alpha	2
Mesa3D	Software development	11/3/1999	GNU General Public License (GPL)	23	mature	1
mged	Database	12/6/2000	MIT License	45	beta	2
MinGW - Minimalist GNU for Windows	Software development	2/9/2000	OSI-Approved Open Source	55	mature	2
Miranda	Communications	2/2/2000	GNU General Public License (GPL)	16	beta	2
Modplug	Multimedia	1/24/2004	GNU General Public License (GPL)	10	production	1
MonetDB	Database	7/2/2002		31	production	2
Multi-Threaded DAAP Daemon	Internet	12/27/2003	GNU General Public License (GPL)	8	alpha	1
NASA World Wind	Education	12/16/2002	NASA Open Source Agreement	16	production	2
Natural Resources Database	Database	12/23/2004	GNU General Public License (GPL)	8	production	1
net-snmp	Internet	10/10/2000	BSD License	15	mature	1

New Scid	Database	3/13/2005	GNU General Public License (GPL)	7	planning	1
NHibernate	Database	2/11/2003	GNU Library or Lesser General Public License (LGPL)	14	production	2
NSLU	Software development	8/10/2004	BSD License	87	beta	4
Nucleus CMS	Internet	11/5/2002	GNU General Public License (GPL)	7	production	1
Nullsoft Scriptable Install System	Software development	3/5/2001	zlib/libpng License	11	mature	1
Numerical Python	Games/Entertainment	1/12/2000	OSI-Approved Open Source	17	alpha	3
OFSET	Education	10/22/2000	GNU General Public License (GPL)	22	production	1
OGRE (O-O Graphics Rendering Engine):	Multimedia	2/25/2000	GNU Library or Lesser General Public License (LGPL)	43	production	5
OmegaT	text editor	11/28/2002	GNU General Public License (GPL)	10	production	1
Open Computer Vision Library	Scientific/Engineering	3/15/2001	BSD License	15	beta	1
Open Far Plugins	Desktop Environment	4/25/2002	Other/Proprietary License	10	beta	1
OpenBabel	Scientific/Engineering	11/25/2001	GNU General Public License (GPL)	14	beta	1
OpenFi	Multimedia	7/5/2005	GNU General Public License (GPL)	5	beta	1
OpenKore	Games/Entertainment	11/7/2003	GNU General Public License (GPL)	28	mature	1
OpenNMS	Internet	3/29/2000	GNU General Public License (GPL)	25	production	2
OpenTibia	Games/Entertainment	7/31/2001	GNU General Public License (GPL)	17	alpha	2
OpenTTD	Games/Entertainment	3/6/2004	GNU General Public License (GPL)	12	production	1
OpenWFE	Business applications	5/29/2002	BSD License	10	production	1
OProfile	Software development	12/8/2000	GNU General Public License (GPL)	6	alpha	1
OsiriX - 3D DICOM Medical Viewer for MacOS X	Scientific/Engineering	4/16/2004	GNU General Public License (GPL)	14	mature	1
PCGen :: An RPG Character Generator	Games/Entertainment	4/18/2001	GNU Library or Lesser General Public License (LGPL)	68	production	4
PeerGuardian	Communications	2/16/2005	GNU General Public License (GPL)	14	beta	1
Phantasmal MUDLib for DGD	Games/Entertainment	3/10/2002	Public Domain	4	alpha	1
phpCollab	Communications	2/12/2002	GNU General Public License (GPL)	9	production	1
PHPeclipse - PHP/SQL/HTML Eclipse-Plugin	Software development	7/11/2002	Common Public License	30	beta	2
phpWebSite Community Development	Internet	5/16/2003	OSI-Approved Open Source	31	beta	2
PhpWiki	Database	5/25/2000	GNU General Public License (GPL)	13	beta	2
Player/Stage/Gazebo	Education	12/19/2001	GNU General Public License (GPL)	24	beta	2
Plone	Internet	2/20/2002	GNU General Public License (GPL)	88	production	6

PMD	Software development	6/21/2002	BSD License	11	production	2
POPFile - Automatic Email Classification	Communications	9/22/2002	GNU General Public License (GPL)	8	production	1
Porthole	Systems Administration	12/2/2003	GNU General Public License (GPL)	6	production	1
PRADO: PHP component framework	Internet	8/30/2004	BSD License	12	beta	1
Privoxy	Internet	9/9/2000	GNU General Public License (GPL)	19	production	1
Psycle Modular Music Creation Studio	Multimedia	9/4/2000	GNU General Public License (GPL)	25	production	2
qooxdoo	Software development	1/27/2005	GNU Library or Lesser General Public License (LGPL)	11	alpha	1
QuantLib	Business applications	10/11/2000	BSD License	20	beta	1
Quantum GIS	Scientific/Engineering	6/15/2002	GNU General Public License (GPL)	18	beta	4
RealTimeBattle	Games/Entertainment	12/5/1999	GNU General Public License (GPL)	23	pre-alpha	2
Rosegarden	Desktop Environment	4/23/2000	GNU General Public License (GPL)	13	production	2
Roundup Issue Tracker	Communications	7/18/2001	Python License (CNRI Python License)	8	production	2
rt2400/rt2500 Linux Driver	Systems Administration	4/23/2004	GNU General Public License (GPL)	5	beta	1
RUNA WFE	Business applications	11/26/2004	GNU General Public License (GPL)	8	production	1
saf-test	Software development	8/24/2004	GNU General Public License (GPL)	28	alpha	1
Seagull PHP Application Framework	Internet	10/14/2003	BSD License	24	production	5
sforce	Internet	12/6/2003		13	alpha	1
Shareaza	Communications	5/28/2004	GNU General Public License (GPL)	11	production	1
SimpleTest	Software development	3/16/2003	GNU Library or Lesser General Public License (LGPL)	7	production	2
SmallBASIC	Software development	3/8/2001	GNU General Public License (GPL)	15	production	1
Smart Common Input Method platform	Desktop Environment	5/1/2004	GNU General Public License (GPL)	15	production	1
SmartWin++	Desktop Environment	10/12/2003	BSD License	9	mature	1
SNAP Platform and SNAPPIX	Software development	3/23/2001	Apache Software License	15	beta	2
SoX - Sound eXchange	Multimedia	9/1/2000	GNU Library or Lesser General Public License (LGPL)	5	production	1
SpamBayes anti-spam	Communications	9/3/2002	Python Software Foundation License	26	production	3
SpeedSim	Games/Entertainment	10/25/2004	GNU General Public License (GPL)	7	production	1
SQLObject	Database	2/18/2003	GNU Library or Lesser General Public License (LGPL)	6	production	1
SQuirreL SQL Client	Database	5/31/2001	GNU General Public License (GPL)	25	beta	1
SquirrelMail	Internet	11/18/1999	GNU General Public License (GPL)	24	production	1
Star Control	Games/Entertainment	10/22/2000	Public Domain	8	beta	1

Steel Bank Common Lisp	Software development	1/12/2000	GNU General Public License (GPL)	19	beta	1
Stellarium	Scientific/Engineering	3/13/2002	GNU General Public License (GPL)	4	production	1
StepMania	Games/Entertainment	10/16/2001	MIT License	22	production	4
Struts Applications	Communications	3/20/2002	Apache Software License	27	production	1
SW Test Automation Framework	Software development	8/8/2001	Common Public License	9	production	1
SWIG	Software development	1/19/2000	Apache License V2.0, BSD License	20	planning	1
Sylpheed-Claws	Communications	4/18/2001	GNU General Public License (GPL)	10	production	1
SynCE	Communications	7/2/2001	MIT License	15	beta	2
Taverna	Education	2/24/2003	GNU Library or Lesser General Public License (LGPL)	17	alpha	1
tcllib	Software development	10/13/2000	BSD License	52	beta	1
tDiary	Communications	2/19/2002	GNU General Public License (GPL)	25	production	1
TerraIM	Communications	9/19/2002	GNU General Public License (GPL)	5	production	1
The Adobe Source Libraries (ASL)	Software development	2/25/2005	MIT License	9	alpha	1
The CvsGui project	Systems Administration	8/19/2000	GNU General Public License (GPL)	7	beta	2
The Freenet Project	Internet	12/28/1999	GNU General Public License (GPL)	61	alpha	1
The Mana World (TMW)	Games/Entertainment	4/11/2004	GNU General Public License (GPL)	37	pre-alpha	7
The Plone Collective	Internet	6/7/2002	OSI-Approved Open Source	256	production	4
The Search Engine Project	Internet	4/19/2004	GNU General Public License (GPL)	8	beta	2
The Seashore Project	Multimedia	1/15/2003	GNU General Public License (GPL)	5	beta	1
Thinstation	terminals	5/4/2003	GNU General Public License (GPL)	4	production	1
Tiki CMS/Groupware	Internet	10/7/2002	GNU Library or Lesser General Public License (LGPL)	325	beta	13
Tilda	terminals	12/8/2004	GNU General Public License (GPL)	7	production	3
Tool Command Language (Tcl)	Desktop Environment	9/5/2000	BSD License	47	mature	1
TortoiseCVS	Systems Administration	3/3/2002	GNU General Public License (GPL)	39	production	1
Turn Based Strategy Game Engine	Games/Entertainment	1/18/2002	GNU General Public License (GPL)	8	production	1
tvtime	Multimedia	10/8/2002	GNU General Public License (GPL)	22	beta	2
TYPO3	Database	2/12/2001	GNU General Public License (GPL)	17	mature	2
UFRaw (Unidentified Flying Raw)	Multimedia	12/31/2004	GNU General Public License (GPL)	4	alpha	1
Undernet IRC Server Development	Communications	9/26/2002	GNU General Public License (GPL)	15	production	1
UNICORE (Uniform Interface to Computing Resources)	Internet	2/13/2004	OSI-Approved Open Source	38	production	2
VirtualDubMod	Multimedia	10/28/2002	GNU General Public License (GPL)	8	alpha	1

vtiger CRM	Business applications	8/23/2004	Mozilla Public License 1.1 (MPL 1.1)	22	beta	1
Web Survey Toolbox	Database	5/9/2003	GNU General Public License (GPL)	20	alpha	1
WebCalendar	Business applications	3/22/2000	GNU General Public License (GPL)	5	beta	1
WebMacro	Software development	10/11/2002	Apache Software License	8	mature	1
Windows Installer XML (WiX)	Systems Administration	3/31/2004	Common Public License	17	beta	3
Wine Is Not an Emulator	Systems Administration	5/28/2000	GNU Library or Lesser General Public License (LGPL)	13	beta	3
Wings 3D	Multimedia	8/7/2001	BSD License	8	beta	1
WinMerge	Systems Administration	10/20/2000	GNU General Public License (GPL)	11	production	1
wxCode	Software development	4/14/2002	wxWindows Library Licence	23	production	1
wxMaxima	Scientific/Engineering	12/16/2004	GNU General Public License (GPL)	6	beta	1
XboxMediaCenter (XBMC)	Games/Entertainment	8/1/2003	GNU General Public License (GPL)	56	mature	1
XCSoar	Multimedia	6/16/2005	GNU General Public License (GPL)	10	alpha	1
XLIL - Xlink Linux Installer + Launcher	Games/Entertainment	8/11/2005	GNU General Public License (GPL)	5	production	1
XMLTV	Internet	10/31/2001	GNU General Public License (GPL)	25	beta	3
XOOPS Dynamic Web CMS	Software development	12/6/2001	GNU General Public License (GPL)	109	beta	4
XUI	Database	3/18/2003	Mozilla Public License 1.1 (MPL 1.1)	6	production	2
Yabause	Games/Entertainment	9/11/2003	GNU General Public License (GPL)	10	alpha	3
YaBB (Yet another Bulletin Board)	Communications	7/30/2000	Other/Proprietary License	17	beta	2
Zapping, a Gnome TV viewer	Multimedia	2/14/2000	GNU General Public License (GPL)	6	alpha	1
ZeosLib	Database	9/18/2001	GNU General Public License (GPL)	16	production	1
ZSNES	Games/Entertainment	2/2/2001	GNU General Public License (GPL)	13	beta	1

Appendix D: Open Source Projects Participation Activities and Software Downloads

Project Name	Download	Tracker(Total)	Tracker(Open)	Forum	Mail	CVS (Commits)	CVS(Adds)
.NetTiers: OR mapper codesmith template	11460	153	42				
]project-open[	14551	335	96	607	2		
Adium	831952	40	3		25194	2639	610
Alfresco Content Management	1267						
Allegro game programming library	469526	150	13		56360	9414	2019
Ambulant	26226	291	84		7293		
AMFPHP (Flash Remoting for PHP)	88611	61	2	414	2920	122	50
AMIS	1522	18	9	2	1657		
AMSN (Alvaro's Messenger)	5245148	2073	146		19859	1962	407
AMX Mod X	706927						
AndroMDA	58428				36491	266	161
Anjuta C/C++ IDE	410872			1281	8492	94	22
Anope IRC Services	97040				87		
APLAWS	11250	93	50	1850	2832		
APS/NWNX	7984	8	8	13		5	
Aqsis Renderer	74559	204	33		9383	4330	922
Armagetron Advanced	169734	204	42	34			
Artificial Knowledge Interface for Reasoning Applications	1508	5	1	7	27		
ATLAS (Automatically Tuned Linear Algebra Software)	71300	476	42	38	1513	2114	5866
ATMEL Linux PCI PCMCIA USB Drivers	81386	153	141	358	1665	303	18
Audacity	7810226				63626	7131	2533
BASE(Basic Analysis and Security Engine)	42116	184	29	658	1087		
BibDesk	95783	660	78		13634	110	173
Big Sister	172071	738	206		4068	959	228
bitweaver	4574	182	82	5	7666		
Boa Constructor - wxPython GUI Builder	202987	388	147	1204	2938	1816	1087
Boost C++ Libraries	533640	531	176	17	6627	27097	10992
Boson	68595				13044	8096	2593

BRL-CAD	28003	97	46	437	4477		
Btech-Online Battletech MUX	2001	172	35		1007		
Bugzilla Test Runner	7110	100	34	327	27		
ByteHoard	23670				93		
CARE2X php Integ Hospital Info System	63918	54	30	79	6553	1415	1762
Checkstyle	132206	912	154		10241	3401	764
Chicken of the VNC	421415	345	91	256	1602	208	16
ChurchInfo	2111	81	7	314			
Cisco-centric Open Source Initiative	100319	8	5	75	141	375	106
Clam AntiVirus	799118					107	
ClamWin Free Antivirus	1584817	586	172	658	338		
CMU Sphinx	150140	205	67	4203	73	6343	1910
Cobertura	8502	102	24		684		
Code::Blocks	88153	828	249				
Community Mapbuilder	5511	164	45		3557	10	12
Conky	6820	99	26	34	444		
Crazy Eddie's GUI System	32682	97	22		2942		
Danger from the Deep	25583	8	2		179	697	252
Dark Oberon	43214	151	49	225	3	596	100
Dave's Quick Search Deskbar	29163	209	49		5648	2555	548
DBE Studio	380	81	16	8	14		
devkitPro	54558	22	5		90		
Distributed Generic Information Retrieval (DiGIR)	3916	48	21	25	939	848	537
DOSEMU for Linux	351695	586	66			134	2
Dropline GNOME	2081042	94	4		5637	105	12
DrPython	81761	172	36	1577			
Druid, The Database Manager	53547	131	27	395	1351	474	940
DScaler Deinterlacer/Scaler	3661948	566	295		17951	8924	1361
EasyH10	20626	23			76		
EasyMOD	68494	36	9		266		
eGroupWare: Enterprise Collaboration	654399	3343	996		48202	1082	1424
eLML - eLesson Markup Language	454	90	10	2	37		
Enlightenment	1080269				54602	15954	4673

eXist	109570	145	43		13492	3503	2013
FBIde	12781	4	4	3			
Finance::Quote	17805	71	5	100	304	434	82
Fink	2058652	2482	563		116748	18644	23871
FlameRobin	28703	118	38		2536		
floAt's Mobile Agent	2606166	1628	696		2	46	24
FreeGuide TV Guide	80112				5054	731	263
FreeImage	232506	103	28	2898	23		
FreeMarker	58178	192	57	813	17036	10235	1592
FreePOPs	803942	54	17		21		
Freevo - Home Theatre PC Platform	245251	85	23		37742		
Gaim	10201615	17439	2480	15266	40812	13529	3435
Gallery	3587160	3727	601		50769	10919	2819
Ganttproject	606607	718	341	2107	166	467	56
GDPDM	24			2	17		
Gene Ontology	21680	255	48	13	1620	949	395
Generic Model Organism System Database	21646	187	56	74	24557	11564	2703
GeoTools, the java GIS toolkit	191432	292	109		29390		
GFP	17794	7		45	7		
Gimp-Print - Top Quality Printer Drivers	1145920	1348	517	6121	14866	9790	995
GnuWin32	4329610	327	102	632	1193		
Gourmet	54345	191	58	258	188		
gPhoto	347704	895	167		13221	14425	1783
GPU, a Global Processing Unit	18882	62	2		657	292	80
Group-Office	97084	518	105			899	775
GTK+ Gnutella	349328	808	136		7316	6840	527
Guido van Robot	8854	11	3		2864	17	10
guifications	205297	161	22	420	2444		
HSQL Database Engine	496324	1086	198	10172	7171	2604	1128
Inkscape	751125	3303	857	175	44972		
iPodder	1187598	731	399		30		
J2EE Certificate Authority, EJBCA	28658	27	2	1600	756	3387	740
JabRef	110705	598	280	711	177		
JasperReports	546209	579	88	19720	2284	774	291

Java Modeling Language (JML)	7797	517	199		7944	4470	1862
Java Object Oriented Neural Engine	125817	129	20	2236		1444	639
JavaGroups	63994			660	8979	3862	682
JBoss.org	6722334	3088	101		295989		
JFreeReport	247605	131	6		11	8086	1015
jGuard	7094	45	17	512	10		
JiBX - XML Data Binding for Java	13984				4008	266	215
Jmol	66313	428	134		17742	3376	609
JMRI Model Railroad Interface	57181	390	110	4	7749	4316	1481
JSBSim Flight Dynamics Model	4294	76	28	32	7122	2919	165
JVoiceXML	7193			88	240		
Jython	342849	538	171		13281	1882	872
KeePass Password Safe	496574	1009	283	3649			
KMyMoney	77015	343	86		9336	3453	474
Koha	114808	17	9	15	17408	4293	2698
KoLmafia	98108	287	19	132			
Krusader	246313	558	59		3305	1111	87
LabPlot	19619	48	4	22	343		
LAME (Lame Aint an MP3 Encoder)	1505170	314	49	62	8670	7988	354
LEAF - Linux Embedded Appliance Firewall	330187	172	28		35287	1314	1155
Licq	1670954	1291	187	270	23466	1224	173
LifeLines	39666	276	29	37	835	5989	448
Liferay Portal	287402				22672	31641	1762
LinPHA	60917	439	67	3340		1650	81
lphantGUI							
macam - webcam driver for Mac OS X	208523	173	111	190	128	309	66
Magnolia	115483			33			
MailWatch for MailScanner	16459	73	36	585	4025	65	11
Mantis	202243				9257	10691	746
Mapbender	23556	10	4	6	2659		
Maven Plugins	6572	107	60		1968	238	178
Maxima -- GPL CAS based on DOE-MACSYMA	205489	902	586	45	5600	1111	1041
MediaWiki	447425	1775	400			2574	280

MegaMek	252733	2906	376	6690	7853	2773	1905
MekWars	1142	300	25	58	3519		
Mesa3D	1408780	574	53		20388		
mged	23954	43	29		4314	9626	3257
MinGW - Minimalist GNU for Windows	3965920	1255	293	2420	38877	2247	1444
Miranda	4360116				14	5922	826
Modplug	40986				127		
MonetDB	10806	857	94		5932	4403	429
Multi-Threaded DAAP Daemon	20956	54	19	246	547		
NASA World Wind	6790168	197	129		1397		
Natural Resources Database	7834	15	10	57	5		
net-snmp	1102199	2255	401		73040	9006	907
New Scid	634	2	2	5	914		
NHibernate	93416			5295	5208	194	70
NSLU	41643				696		
Nucleus CMS	224792					483	43
Nullsoft Scriptable Install System	669248	792	147		3093	4497	414
Numerical Python	554362	886	130	293	5463	2911	349
OFSET	160713	85	59	14	1886	1935	1368
OGRE (O-O Graphics Rendering Engine):	610517	466	33		15334	6923	5935
OmegaT	20882	276	86		3206	120	9
Open Computer Vision Library	862571	165	110	159	808	775	1228
Open Far Plugins	2867				218	178	13
OpenBabel	32784	265	92		3772	1368	1588
OpenFi	5285	50	44	33			
OpenKore	1240903				2488		
OpenNMS	96294				34180	1911	276
OpenTibia	95631	13	9	354	12	300	46
OpenTTD	293429	2105	358		25		
OpenWFE	43429	832	84	5154	5631	1560	639
OProfile	36514	140	13		10768	7085	756
OsiriX - 3D DICOM Medical Viewer for MacOS X	38249	16	6	3			
PCGen :: An RPG Character Generator	1118291	4620	515	2163	4630	23577	3575

PeerGuardian	2849214	225	87	37	16		
Phantasmal MUDLib for DGD	2423	48	1	555	2168	766	186
phpCollab	160522	244	129			1124	548
PHPeclipse - PHP/SQL/HTML Eclipse-Plugin	447839	402	215		4777	1264	1013
phpWebSite Community Development	60847	376	107		4284	181	65
PhpWiki	206013	870	223	1969	13779	4967	828
Player/Stage/Gazebo	41834	342	150		5461	7486	2127
Plone	515596				152652		
PMD	174617	943	151	3397	9384	5169	1316
POPFile - Automatic Email Classification	584947	2143	231	36103	3560	1498	386
Porthole	3167	179	38	41	1460		
PRADO: PHP component framework	34578	225	43	2	1864		
Privoxy	606103	1863	710		11693	4396	518
Psycle Modular Music Creation Studio	39952	46	2			2070	134
qooxdoo	7359	2	2		1585		
QuantLib	111596	54	9		20801	18175	2621
Quantum GIS	54169	702	171	10	10486	802	201
RealTimeBattle	13973	44		2	562	2211	354
Rosegarden	63458	1114	373		27177	15771	2257
Roundup Issue Tracker	31853	864	116		17406	3599	449
rt2400/rt2500 Linux Driver	117190	198	22	1890	4489		
RUNA WFE	2922	45	34	230			
saf-test	601	882	45	3	749		
Seagull PHP Application Framework	27715				11253		
sforce	33683	16	12	5			
Shareaza	16158527	248	76				
SimpleTest	19414	107	12		1478	372	30
SmallBASIC	190431					588	299
Smart Common Input Method platform	73611	68	19	67		2149	
SmartWin++	13333	96	25	921	2326		
SNAP Platform and SNAPPIX	7729	594	73	4458	352		
SoX - Sound eXchange	246170	98	59		1423	770	36
SpamBayes anti-spam	899361	1126	163			1813	329

SpeedSim	1323520	6	3	22			
SQLObject	11366	187	41		6450		
SQuirreL SQL Client	377257	494	166		2985	3355	1229
SquirrelMail	1810966	3300	427		72837	9443	2002
Star Control	9593	16	14	9	1251	549	826
Steel Bank Common Lisp	38082				16376	9896	482
Stellarium	543787	366	121	1366		1640	109
StepMania	2319119	2669	214		40125	15138	9565
Struts Applications	247065	35	20	378	4955	946	699
SW Test Automation Framework	92327	1179	349	3058	1432	1898	996
SWIG	248374	807	102		4430		
Sylpheed-Claws	163482	762	206	258	45960	15773	984
SynCE	248868	75	33	2956	6428	1550	468
Taverna	12681	129	50		1872	315	196
tcllib	85967	1108	288	49	8631	2774	477
tDiary	6855	5	3		7904	2437	865
TerraIM	75382	164	30	392		73	9
The Adobe Source Libraries (ASL)	13530	15	5	48	1666		
The CvsGui project	4375636	1480	141			7195	1910
The Freenet Project	1485713					18931	4616
The Mana World (TMW)	29542	28	2		1397		
The Plone Collective	232277	997	276		27991	3224	1372
The Search Engine Project	34635	45	8	1422			
The Seashore Project	56716	16	8	326			
Thinstation	103628	18	10		15104		
Tiki CMS/Groupware	411378	3263	1117		35008	7176	2424
Tilda	3093	6	3	20			
Tool Command Language (Tcl)	1751877	4330	566		55693	7893	215
TortoiseCVS	1196927	1656	251		6577	4739	487
Turn Based Strategy Game Engine	43324	354	64		191	263	48
tvtime	128458	641	227		3107	2698	297
TYPO3	1325737					202	
UFRaw (Unidentified Flying Raw)	20274	43	16	457	112		
Undernet IRC Server Development	55812	219	43			454	183

UNICORE (Uniform Interface to Computing Resources)	9844	93	63		4925		
VirtualDubMod	3381510	473	191	147	192	1667	1295
vtiger CRM	150978	412	31	81	4337		
Web Survey Toolbox	3583	11	4	160		24	8
WebCalendar	483908	2369	261	17438	4	1000	73
WebMacro	12875	11	3		3345	556	92
Windows Installer XML (WiX)	191431	631	185		10437		
Wine Is Not an Emulator	3189640						
Wings 3D	521308	329	129	10		3664	142
WinMerge	1104976	3483	357	2249	197	1247	226
wxCode	16166	25	5		562		
wxMaxima	11824	32	6	169	12		
XboxMediaCenter (XBMC)	412819	2118	578		12636	1090	894
XCSoar	4417	63	39	11	534		
XLIL - Xlink Linux Installer + Launcher	2402			2			
XMLTV	392693	405	58		10748	1645	1076
XOOPS Dynamic Web CMS	3031471	850	235	795	9605	4915	2116
XUI	32081	194	24	761	34	499	330
Yabause	33366	10	4	18	559		
YaBB (Yet another Bulletin Board)	341055	68				1222	615
Zapping, a Gnome TV viewer	145105	204	39		1575	8348	1008
ZeosLib	375145	712	194		1520	2475	918
ZSNES	10271073	207	52		566	2827	98

Appendix E: Results of Supplemental Study

Results with Data Set 1:

Standardized Path Estimates

Path	Estimate	t-value	p-value
Professional Benefits → Participation	0.2520	4.20	<0.001
Enjoyment → Participation	0.0830	1.17	n.s.
Identification → Participation	0.4420	5.41	<0.001
Obligation → Participation	0.1556	1.88	<0.05
Shared Goals → Enjoyment	0.1786	2.28	<0.05
Cognitive Trust → Enjoyment	0.0233	0.28	n.s.
Affective Trust → Enjoyment	0.3499	4.49	<0.001
Leader Support → Enjoyment	0.3805	4.28	<0.001
Shared Goals → Identification	0.2571	2.85	<0.05
Cognitive Trust → Identification	-0.1684	-1.17	n.s.
Affective Trust → Identification	0.6554	6.15	<0.001
Leader Support → Identification	-0.0182	0.02	n.s.
Shared Goals → Obligation	0.2977	3.06	<0.05
Cognitive Trust → Obligation	0.0011	0.01	n.s.
Affective Trust → Obligation	0.4971	4.84	<0.001
Leader Support → Obligation	0.0800	0.81	n.s.

Chi-square:	463.02
Chi-square DF:	249
RMSEA:	0.0590
GFI:	0.8731
AGFI:	0.8344
CFI:	0.9482
NFI:	0.8956
NNFI:	0.9376

Results with Data Set 2:

Standardized Path Estimates

Path	Estimate	t-value	p-value
Professional Benefits → Participation	0.1009	1.79	<0.05
Enjoyment → Participation	0.0808	1.10	n.s.
Identification → Participation	0.4356	5.57	<0.001
Obligation → Participation	0.2709	3.23	<0.05
Shared Goals → Enjoyment	0.2110	2.61	<0.05
Cognitive Trust → Enjoyment	0.2284	2.52	<0.05
Affective Trust → Enjoyment	0.3069	4.59	<0.001
Leader Support → Enjoyment	0.2116	2.72	<0.05
Shared Goals → Identification	0.3145	3.22	<0.05
Cognitive Trust → Identification	-0.0386	0.37	n.s.
Affective Trust → Identification	0.5352	6.11	<0.001
Leader Support → Identification	-0.1325	-1.14	n.s.
Shared Goals → Obligation	0.3417	3.33	<0.05
Cognitive Trust → Obligation	-0.0001	-0.01	n.s.
Affective Trust → Obligation	0.3843	4.51	<0.001
Leader Support → Obligation	0.1834	1.96	<0.05

Chi-square:	458.30
Chi-square DF:	249
RMSEA:	0.0583
GFI:	0.8746
AGFI:	0.8363
CFI:	0.9491
NFI:	0.8961
NNFI:	0.9387

Results with Data Set 3:

Standardized Path Estimates

Path	Estimate	t-value	p-value
Professional Benefits → Participation	0.2239	3.61	<0.05
Enjoyment → Participation	0.0809	1.12	n.s.
Identification → Participation	0.4050	4.64	<0.001
Obligation → Participation	0.1856	2.02	<0.05
Shared Goals → Enjoyment	0.1392	1.54	<0.1
Cognitive Trust → Enjoyment	0.0877	0.89	n.s.
Affective Trust → Enjoyment	0.2989	3.40	<0.05
Leader Support → Enjoyment	0.3761	3.85	<0.05
Shared Goals → Identification	0.0947	0.88	n.s.
Cognitive Trust → Identification	-0.2366	-1.92	<0.05
Affective Trust → Identification	0.8420	5.55	<0.001
Leader Support → Identification	0.0139	0.13	n.s.
Shared Goals → Obligation	0.1865	1.72	<0.05
Cognitive Trust → Obligation	-0.0509	-0.43	n.s.
Affective Trust → Obligation	0.6130	4.70	<0.001
Leader Support → Obligation	0.1272	1.16	n.s.

Chi-square:	467.20
Chi-square DF:	249
RMSEA:	0.0596
GFI:	0.8736
AGFI:	0.8351
CFI:	0.9449
NFI:	0.8904
NNFI:	0.9336

Results with Data Set 4:

Standardized Path Estimates

Path	Estimate	t-value	p-value
Professional Benefits → Participation	0.1316	2.25	<0.05
Enjoyment → Participation	0.0919	1.22	n.s.
Identification → Participation	0.4002	4.84	<0.001
Obligation → Participation	0.2643	2.30	<0.05
Shared Goals → Enjoyment	0.0585	0.76	n.s.
Cognitive Trust → Enjoyment	0.1829	2.28	<0.05
Affective Trust → Enjoyment	0.3953	5.18	<0.001
Leader Support → Enjoyment	0.3342	3.95	<0.05
Shared Goals → Identification	0.2458	2.59	<0.05
Cognitive Trust → Identification	-0.0076	-0.08	n.s.
Affective Trust → Identification	0.6332	5.98	<0.001
Leader Support → Identification	-0.0680	-0.70	n.s.
Shared Goals → Obligation	0.2197	2.26	<0.05
Cognitive Trust → Obligation	0.0618	0.63	n.s.
Affective Trust → Obligation	0.4565	4.67	<0.001
Leader Support → Obligation	0.1803	1.80	<0.1

Chi-square:	474.04
Chi-square DF:	249
RMSEA:	0.0605
GFI:	0.8676
AGFI:	0.8272
CFI:	0.9460
NFI:	0.8938
NNFI:	0.9349

Results with Data Set 5:

Standardized Path Estimates

Path	Estimate	t-value	p-value
Professional Benefits → Participation	0.1645	2.83	<0.05
Enjoyment → Participation	0.0456	0.64	n.s.
Identification → Participation	0.4425	5.68	<0.001
Obligation → Participation	0.2708	3.35	<0.05
Shared Goals → Enjoyment	0.2020	2.55	<0.05
Cognitive Trust → Enjoyment	0.2423	2.67	<0.05
Affective Trust → Enjoyment	0.2878	4.09	<0.001
Leader Support → Enjoyment	0.2150	2.74	<0.05
Shared Goals → Identification	0.2643	2.85	<0.05
Cognitive Trust → Identification	0.0950	0.92	n.s.
Affective Trust → Identification	0.4930	5.53	<0.001
Leader Support → Identification	-0.0990	-1.10	n.s.
Shared Goals → Obligation	0.3045	3.12	<0.05
Cognitive Trust → Obligation	0.0161	0.15	n.s.
Affective Trust → Obligation	0.4242	4.64	<0.001
Leader Support → Obligation	0.1367	1.48	<0.1

Chi-square:	454.21
Chi-square DF:	249
RMSEA:	0.0578
GFI:	0.8743
AGFI:	0.8360
CFI:	0.9492
NFI:	0.8953
NNFI:	0.9388

Results with Data Set 6:

Standardized Path Estimates

Path	Estimate	t-value	p-value
Professional Benefits → Participation	0.1011	1.77	<0.05
Enjoyment → Participation	0.0569	0.77	n.s.
Identification → Participation	0.4470	5.48	<0.001
Obligation → Participation	0.2751	3.23	<0.05
Shared Goals → Enjoyment	0.2498	2.96	<0.05
Cognitive Trust → Enjoyment	0.1908	2.21	<0.05
Affective Trust → Enjoyment	0.2726	4.09	<0.001
Leader Support → Enjoyment	0.2544	3.06	<0.05
Shared Goals → Identification	0.3099	3.10	<0.05
Cognitive Trust → Identification	-0.0056	-0.06	n.s.
Affective Trust → Identification	0.5723	6.28	<0.001
Leader Support → Identification	-0.1190	-1.25	n.s.
Shared Goals → Obligation	0.2981	2.81	<0.05
Cognitive Trust → Obligation	0.0352	0.34	n.s.
Affective Trust → Obligation	0.4225	4.71	<0.001
Leader Support → Obligation	0.1128	1.12	n.s.

Chi-square:	449.11
Chi-square DF:	249
RMSEA:	0.0570
GFI:	0.8770
AGFI:	0.8394
CFI:	0.9486
NFI:	0.8929
NNFI:	0.9381

Results with Data Set 7:

Standardized Path Estimates

Path	Estimate	t-value	p-value
Professional Benefits → Participation	0.1327	2.21	<0.05
Enjoyment → Participation	0.1094	1.47	<0.1
Identification → Participation	0.4017	4.98	<0.001
Obligation → Participation	0.2449	2.81	<0.05
Shared Goals → Enjoyment	0.1434	1.68	<0.1
Cognitive Trust → Enjoyment	0.0583	0.65	n.s.
Affective Trust → Enjoyment	0.3286	4.26	<0.001
Leader Support → Enjoyment	0.4004	4.15	<0.001
Shared Goals → Identification	0.2873	2.81	<0.05
Cognitive Trust → Identification	-0.0626	-0.60	n.s.
Affective Trust → Identification	0.5908	5.81	<0.001
Leader Support → Identification	-0.1019	-0.98	n.s.
Shared Goals → Obligation	0.3101	2.93	<0.05
Cognitive Trust → Obligation	0.0939	0.89	n.s.
Affective Trust → Obligation	0.4464	4.56	<0.001
Leader Support → Obligation	0.0287	0.27	n.s.

Chi-square:	482.72
Chi-square DF:	249
RMSEA:	0.0619
GFI:	0.8678
AGFI:	0.8274
CFI:	0.9386
NFI:	0.8825
NNFI:	0.9260

Results with Data Set 8:

Standardized Path Estimates

Path	Estimate	t-value	p-value
Professional Benefits → Participation	0.1597	2.67	<0.05
Enjoyment → Participation	0.0419	0.59	<0.1
Identification → Participation	0.4245	5.27	<0.001
Obligation → Participation	0.2750	3.17	<0.05
Shared Goals → Enjoyment	0.1455	1.59	<0.1
Cognitive Trust → Enjoyment	0.1697	1.81	<0.05
Affective Trust → Enjoyment	0.2875	3.70	<0.001
Leader Support → Enjoyment	0.3129	3.30	<0.05
Shared Goals → Identification	0.2993	2.80	<0.05
Cognitive Trust → Identification	0.0088	0.08	n.s.
Affective Trust → Identification	0.6254	5.85	<0.001
Leader Support → Identification	-0.1976	-0.85	n.s.
Shared Goals → Obligation	0.3833	3.39	<0.05
Cognitive Trust → Obligation	0.1373	1.28	<0.1
Affective Trust → Obligation	0.4153	4.29	<0.001
Leader Support → Obligation	-0.0481	-0.46	n.s.

Chi-square:	457.25
Chi-square DF:	249
RMSEA:	0.0582
GFI:	0.8739
AGFI:	0.8354
CFI:	0.9489
NFI:	0.8956
NNFI:	0.9385

Results with Data Set 9:

Standardized Path Estimates

Path	Estimate	t-value	p-value
Professional Benefits → Participation	0.1398	2.39	<0.05
Enjoyment → Participation	0.1142	1.59	<0.1
Identification → Participation	0.3926	4.81	<0.001
Obligation → Participation	0.2418	2.80	<0.05
Shared Goals → Enjoyment	0.1212	1.46	<0.1
Cognitive Trust → Enjoyment	0.1804	1.96	<0.05
Affective Trust → Enjoyment	0.3802	4.49	<0.001
Leader Support → Enjoyment	0.2279	2.90	<0.05
Shared Goals → Identification	0.1863	1.96	<0.05
Cognitive Trust → Identification	-0.1087	-1.00	n.s.
Affective Trust → Identification	0.7008	5.72	<0.001
Leader Support → Identification	-0.0445	-0.50	n.s.
Shared Goals → Obligation	0.3053	3.01	<0.05
Cognitive Trust → Obligation	0.0322	0.30	n.s.
Affective Trust → Obligation	0.4604	4.33	<0.001
Leader Support → Obligation	0.0963	1.06	n.s.

Chi-square:	457.13
Chi-square DF:	249
RMSEA:	0.0582
GFI:	0.8736
AGFI:	0.8350
CFI:	0.9496
NFI:	0.8968
NNFI:	0.9393

Results with Data Set 10

Standardized Path Estimates

Path	Estimate	t-value	p-value
Professional Benefits → Participation	0.1639	2.67	<0.05
Enjoyment → Participation	0.0566	0.77	n.s.
Identification → Participation	0.4410	5.17	<0.001
Obligation → Participation	0.1886	2.04	<0.05
Shared Goals → Enjoyment	0.0816	0.95	n.s.
Cognitive Trust → Enjoyment	0.1534	1.78	<0.05
Affective Trust → Enjoyment	0.2995	3.87	<0.05
Leader Support → Enjoyment	0.3761	4.03	<0.001
Shared Goals → Identification	0.2120	2.18	<0.05
Cognitive Trust → Identification	-0.0389	-0.41	n.s.
Affective Trust → Identification	0.6824	6.26	<0.001
Leader Support → Identification	-0.1088	-1.10	n.s.
Shared Goals → Obligation	0.1817	1.77	<0.05
Cognitive Trust → Obligation	0.1166	1.15	n.s.
Affective Trust → Obligation	0.5287	4.84	<0.001
Leader Support → Obligation	0.0970	0.94	n.s.

Chi-square:	454.03
Chi-square DF:	249
RMSEA:	0.0577
GFI:	0.8779
AGFI:	0.8407
CFI:	0.9493
NFI:	0.8955
NNFI:	0.9389