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Technical Note

How Open Source Software Succeeds? A Review of Research on Success of Open Source Software

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Abstract— **Different aspects of Open Source Software (OSS) have been subject of many research in last decades. Among them many researchers have tried to adopt the pervasive literature of information systems success with this special kind of system development and its specific dimensions. On the other hand the question of success in the OSS development may cover all different aspects of OSS development and help managers and sponsors of OSS projects to evaluate and increase effectiveness of these projects. So drawing a full picture of related research may be beneficial in different ways. In this paper we try to make a systematic review of related literature in the field and specially pay attention to the measures of success, factors affecting the OSS success and research methods used in previous research.**

We discussed measures of success and determinants that affect success of OSS as well as methods used in related research and conclude with some points that may strengthen the quality of further work in the topic.

Keywords-Open Source Software, Open Source Success, Systematic literature review

I. INTRODUCTION

Open Source Software (OSS) is defined by open source initiative as a class of software which allows the user to have access to the source code of the software, having the right and capability to use the software as they see suitable, modify the software in order to create derived work, and redistribute the derivative software free of charge, or at a charge[1]. The specific dimensions of OSS development have attracted attention of both academia and industry, and many different disciplines have paid attention to different aspects of the phenomena.

Developing information system (IS) projects usually entails many different social, behavioral and technical issues and this complexity makes evaluation of their success very complicated. That's why since early 1950s the issue of success in IS has been raised in academic research and in many different work it has been tried to define different models for IS success. DeLone and McLean in 1992 through analysis of all previous research introduced their six factors model of IS success which includes: system quality, information quality, use, user satisfaction, individual impact and organizational

impact[2]. Lots of feedbacks and comments forced them to revise their work after 10 years and presented their seven factors model in 2003 which includes service quality, intention to use and mentions net benefits as measure of success [3].

The usually volunteer nature of development and freely use of OSS as well as dispersed organization of team and many other factors has made the assessment of success in OSS a question for researchers. Moreover according to statistics on sourceforge.net, only 42% of projects go beyond the alpha stage [4] another study reflects that by a sample of 122205 projects on sourceforge.net, only 41608 (34%) were downloaded at least once [5]. Therefore the question of success has attracted many researchers and practitioners in the software industry. Especially in recent years -in which many well known and huge companies start to take advantage of OSS development model- managers and sponsors of OSS projects look for frameworks that help them in assessing and improving success of projects.

Since 2002 many papers has tried to answer this question by defining different models of success for OSS that usually consist of measure(s) of success and some other dependent or independent factor that leads to the defined measure(s) of success. One stream of work in the field is mainly focused on advancing the studies of IS success to the OSS environment and others try to study new factors which are inherently related to OSS development.

In order to draw a picture of previous work in the field of OSS success, we do a systematic literature review in this paper.

Systematic review is a review that aims to comprehensively identify all relevant studies to answer a particular question, and assesses the validity (or soundness) of each study taking this into account when reaching conclusions [6].

Our review has many benefits which are:

- To summarize finding(s) of research in OSS success
- Shows the similarities and antithesis between research for OSS success evaluation
- Makes an opportunity to study context and methodologies of different research on OSS success and map the differences with these parameters
- Makes the opportunity for developing a holistic model of success
- Identifies research gaps and opportunities for future work

The remaining of paper is organized as follows: in section II some frameworks of OSS research are presented, in section III our method and strategy of review is presented, the result of review is presented in section 0, we discuss the findings and propose some suggestions in section V and finally the paper concludes with some points in section VI.

II. Related Work

The growth of research in the field of OSS is remarkable in recent years. Hauge et.al through their literature review for OSS adoption, have investigated only 22 important journals and conferences between 1998 and 2008 and found 1540 research containing the word "Open Source" and 674 papers which were directly related to the field. The trend in the literature is also amazing: while in 1998 there were less than 10 papers related to the field, after the year 2005 the total number has always been more than 100 papers per year [7].

This huge amount of research as well as the diversity of nature of studies (including: software engineering, sociology, MIS, business, etc.) necessitate developing frameworks for reviewing the literature and concentration on a specific research topic in OSS. In this section we study some papers which have reviewed the OSS literature in general and in specific domains.

Review of OSS research

Scacchi et al. in their editorial note categorized recent studies of OSS in four distinct groups [8]. Feller et al. reviewed 155 researches in the area of OSS between 1998 and 2004. They intended to identify the kinds of open source project communities that have been researched, the kinds of research questions that have been asked, and the methodologies used by researchers. They have finally used the concept of "Communities of OSS Development" and classified the literature with regard to the researched community [9].

Stol & Babar studied empirical research in OSS and to do this, reviewed 63 empirical papers in four OSS conferences. This study contains an assessment of quality and some recommendations for improvement. Authors suggested that empirical research in OSS could be classified in four different categories [10].

Von Krogh and von Hippel –on their editorial note in Management Science- categorized the OS research in three different groups [11]. Nelson et al. also defined six phases for OSS development and categorized previous work through these phases [12].

Crowston et al. also reviewed 184 papers from 52 different journals and 40 different conferences. They paid attention to level of analysis, research methods, sample size and project studied, reference discipline and theories, etc. in their quantitative methodology. They also used inputs-mediators-outputs-inputs (IMOI) model and through this model categorized OSS research in 11 different categories [13].

Later Aksulu and Wade, reviewed 618 articles and through a multi-stage, iterative coding process, tried to make a taxonomy of research which includes seven patterns and break downed these patterns into 57 different codes [14]. Amrollahi and Khansari also identified seven groups of stakeholders in OSS environment and suggested it as a framework for OSS research categorization.

Review of specific domains in OSS research

Beside general frameworks for categorizing OSS research, we also found some research that tried to review the related work in one specific category of OSS research: Østerlie & Jaccheri reviewed 52 papers

about OSS development to answer the question: "under what conditions can the view of OSS development as a homogenous phenomenon be made and maintained over time?" [15].

Hauge et al. reviewed 112 papers that provide evidence on how organizations actually adopt OSS [7] and Höst and Alagic reviewed 23 papers to summarize the findings of research that has been carried out on usage of open source components and development methodologies by the industry, as well as companies' participation in the open source community [16].

Ghapanchi, Aurum and Low have also reviewed the measurement of OSS success and developed a taxonomy which consists of two major categories including: Product Success (product quality and user interest) and Project Success (user interest, project activity, project effectiveness, project efficiency) [17]. Although this comprehensive study provides a well structured taxonomy of the success measurements, it doesn't pay attention to variables that affect the success.

III. METHOD OF STUDY

We used the guidelines presented by Kitchenham and Charters in [18] for conducting our research.

Research questions

In the review of related literature, our main aim was to survey perception of authors about concept of success in OSS development and their approach for studying this concept. We follow these questions in reviewing the related papers:

What are the measures of OSS success in the literature?

What are the dependent or independent determinants that affect success of OSS?

What was the research method and scope of study in past research?

Method of review

In first stage of review in November 2010 we searched seven scholar databases1 with word "Open Source Success" and some synonym or related terms such as "Effectiveness of Open Source", "Successful Open Source", "Open Source Maturity", etc. We used following query to search data bases:

(Success OR Effectiveness OR Failure OR Success) AND ("Open Source" OR "Free Software" OR "Libre Software" OR "OSS" OR "FOSS")

We studied keywords and abstract of papers and this initial phase yielded about 40 researches which were related to subject. We then studied all these resources and filtered the related ones. We selected 24 resources in this phase and then made a backward citation analysis and tried to find and review the papers which were cited in these papers. We added 8 resources to previous. Finally our pool of research limited to 32 researches which includes 11 journal papers, 17 conference proceedings and 4 theses. To approve the quality of review we excluded unpublished dissertations and working papers. This filter ends in our final sources of review consisting of 11 journal and 12 conference papers and total amount of 23 papers. A comparative study of these papers in terms of success definition, factors affecting success, research method, scope and number of citation as well as publication years are appeared in appendix 1.

Fortunately, we observe that most of these papers have been published in well known journals (such as: MIS Quarterly, Information System Research, Decision Support Systems, Management Science, etc.) and reputable conferences. We also refer to Google scholar and evaluated number of each paper citation. Here again we observe good statistics in this regard and notice many papers with more than 100 of citations in other resources and average of about 43 citation[2].

Fig.1 and Fig2 present some statistics on reviewed papers.

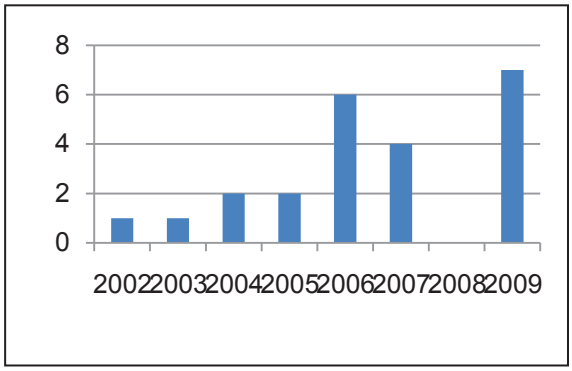

Fig 1. Publication year of the selected papers

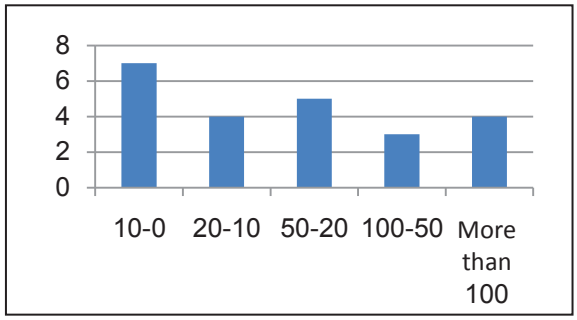

Fig 2. Histogram of reviewed papers' citations

IV. RESULT

Radtke et al. generally classified factors affecting OSS projects in two categories: technical and social [19] and Katsamakas et al. changed the second category to social/legal [20]. Crowston et al. categorized the success definition according to their audience in (users or developers) [21]. Reviewing the related research, we differentiated the final measure(s) of success and the factors affecting measure of success. We then tried to measure the relevance of each item. For this purpose we contrast different parameters and specially paid attention to measure of different parameters. For example parameters like

[1] Science Direct Elsevier, Emerald, Ebscohost, Springer, Jstore, ProQuest, IEEE Xplore,

[2] Notice that this criterion is affected by time of publishes. In other words recent papers may not been cited in many other resources.

"user interest", "number of consumers", "use" and "commercial success" which are related in different papers all measured with "number of downloads" so we finalize the result of study as below:

Measures of OSS success

Reviewing the related papers we code different measures for success of OSS. Although more than 17 different measures could be noticed in related literature but we observed that at least one of the following four measures has been cited in 18 (%78) of papers. Also other measures (such as: project maturity, age of project and number of releases etc.) was also frequent in related literature, but these are the most cited measures of success:

Number of downloads: Which is mentioned in 12 papers as measure for success. This measure is simply assessed by the number of software downloads which is usually tracked by the web site or repository of the software. Number of downloads usually could not be the only measure of success because of the fact that there is usually difference between the number of software downloads and number of actual use of software. This refers to many people who usually download different software but rarely install and use it.

The other point that should be carefully mentioned is the difference of software and their audience. In fact the number of people who download a web browser is different with audience of an expert programming language or professional CRM software. To resolve this problem, researchers use different categories of software and conduct their surveys in each category.

Number of developers: Is stated as measure of success in eight papers. Repositories such as sourceforge.net and freshmeat.net keep detail information about development team of each project and allow researchers to access this database for scientific use. In some cases this amount is asked directly in surveys.

Some work has also differentiated between developers and community members. Developers are people who have directly involved in project's core code while community of project consist of users and developers of project who report bug or provide help for newbie members.

It is supposed that successful software could absorb more developers and the power of community in term of active members could present the success of OSS.

Level of Activity: In nine works, the success of OSS has been measured by the level of activity. Some repositories measure and report activity and activity rank for software. Moreover number of development logs could indicate level of activity in software community.

Bug fixing Power of community: This measure is mentioned in six works. Usually measured by the total amount of fixed bugs in a project or the speed of fixing bugs by developers. The measure reflects the quality of communication in communities.

Factors affecting success of OSS

With the same method we recognized 56 single factors in different research which are not named as final measure of success but factors but may affect the identified measures. Here we observe more extensive social and technical factors. We mention most cited factors here but according to diversity of them, recommend viewing appendix 1 for detail description of the factors.

License Type: Is mentioned in five works. The usual conclusion is that the strictness of license (like those of GPL or strong copyleft licenses) may have different effects on number of downloads and activity and interest of developers and users.

Technical specification of projects: Factors like programming language, operating system, type and audience of software have been mentioned in five papers as factors that may influence success of OSS. The usual inference is that more common infrastructure or platform for software may lead to success of it.

Number of downloads: Three work has analyzed the effect that number of downloads may have on measures of success such as: activity, number of developers and user satisfaction etc.

Number of developers: Is mentioned in three works. Indicators are usually the same as mentioned in section 4.1. It is inferred that increase in number of developers would lead to more activity and more download as well as improvement in maturity of software and team satisfaction.

Research Methods and Scope of Research

We observed different methods in our review: surveys, interviews, mixed-methodology research etc. but the main focus of the research was on validating the proposed methods on OSS repositories. The evaluated scope of research is also different from 3 to more than 40,000 projects.

V. DISCUSSION

In this paper we surveyed some research framework and reviews in the field of open source software and reviewed 23 papers in area of Success of OSS. The subjective nature of success, as well as well as different complicated aspects of IS and OSS development have forced the researchers to specify different indicators for success and define relations between these indicators and factors affecting them.

As shown in Figure 3, our survey shows that most of the success indicators can be categorized in three different groups which are: developer, product and user.

We categorized different factors that affect the success of OSS based on the actor to which they relate in three groups. We also find factors like sponsorship which is related to both developer and product or number of download which relates to both product and user. Same thing could be observed about success indicators and level of activity for example is related to both product and developer.

As could be observed in fig 3, most of factors which affect the success of OSS are related to developers and product and most of success indicators are related to product. Our study shows that user related factors have been studied less than other factors and researchers limited these factors to number of downloads in both success factors and indicators. On top of this research gap, we highlight some other gaps that may help future researchers better define and conduct their study in the field:

Context free research

OSS development takes place in an environment which is highly affected by socio-cultural parameters and specifications of users and development teams of OSS may affect or alter the success parameters of OSS. That's while context of development is usually ignored while studying success of OSS. Except [20] that studies specific kind of software and [4] that verifies the model in Korean software context, we do not find any other research that was based on a specific context. Even these two papers have tried to generalize their findings and the later one mentioned the context based research as a limitation.

So it seems that localizing the issue of success and paying attention to parameters such as: social, cultural and economical state of development community would be beneficial point of view in future research.

Research Methods

As Kirk and Miller stated in [22], "although no one defends a positivistic ontology, but scholars in social science has find out that much research makes sense only in terms of a set of unexamined positivist assumptions." Research in the field of OSS success has the same problem.

We want to precisely point to variables like: "general viewpoint of audience society" and "actual use of software[3]" as measurements of success and contextual parameters such as "availability of knowledgeable developers", "legal support and level of IT development in the development environment" as affecting factors. That's why we recommend mixed-methodology research in the field of OSS success.

Alternatively OSS researches are highly dependent to use of actual data of software. OSS repositories like soursforge.net have provided researchers with great sources for empirical research in the field of OSS. Many others have made spiders to gain data from project pages in such repositories. Although this service made many breakthroughs possible in the field, but it seems that the existence of such service has limited the viewpoint of researchers to factors which are assessable through these sources.

Specifically in the area of OSS success, we observe that %83 of research use repositories' data as part of their work and %74 as the only method of data gathering. It is obvious that so called repositories could not provide data about subjective, social and contextual dimensions of OSS projects and reliance of researchers to this data as the only source may cause ignoring these aspects of development.

Moreover, most well known and sponsored projects have their own website and development community and research which rely only on repositories' information may reflect mostly attitudes of individual developers and pass over the organizational developers and sponsored projects. This problem may affect study of parameters such as number of developers, license type, developer interest, etc.

Lack of toward others' research activities

Although all research in the field of OSS success have tried to study previous work, but we observe little connection between them. One exception is reference [1] which has mentioned four previous works in the model and studied them in a longitudinal study and found some inconsistencies between original and current study.

We believe that study of other work and comparing the results may lead to considering new factors (such as contextual or longitudinal factors) in study of OSS success.

Lack of general models for OSS development

Except initial research by Crowston et al. [23], and Crowston et al. work on the definition of OSS success [21] , we do not find any general model of OSS success. In fact many researches in the field have just tried to validate their partial model of OSS success. We believe that according to wide range of social, cultural and technical factors that may have an effect on success of OSS, developing a general model is not reasonable but we recommend contingency practicesin this regard. In other words we suggest researchers to develop general models for specific contexts and believe that these models would be more helpful in practice.

Lack of locating the research topic in OSS research framework

Previous work on OSS research classification, have usually focused on certain topics such as: developer motivation, adoption, technical issues in management of projects etc. and the success of OSS has rarely been a topic of interest in these class of work. That is in spite of significant body of research and also the central rule of it as final point of OSS development life cycle.

Implication for practicioners

This research could help organizations which sponsor OSS projects to better understand and evaluate success of the projects by providing them with a framework of quantifiable success factors and indicators. Practitioners who want to adopt OSS for their business can also benefit from the factor to evaluate and classify candidate projects.

[3] Although this is a quantifiable measure, for most software such number is unavailable.

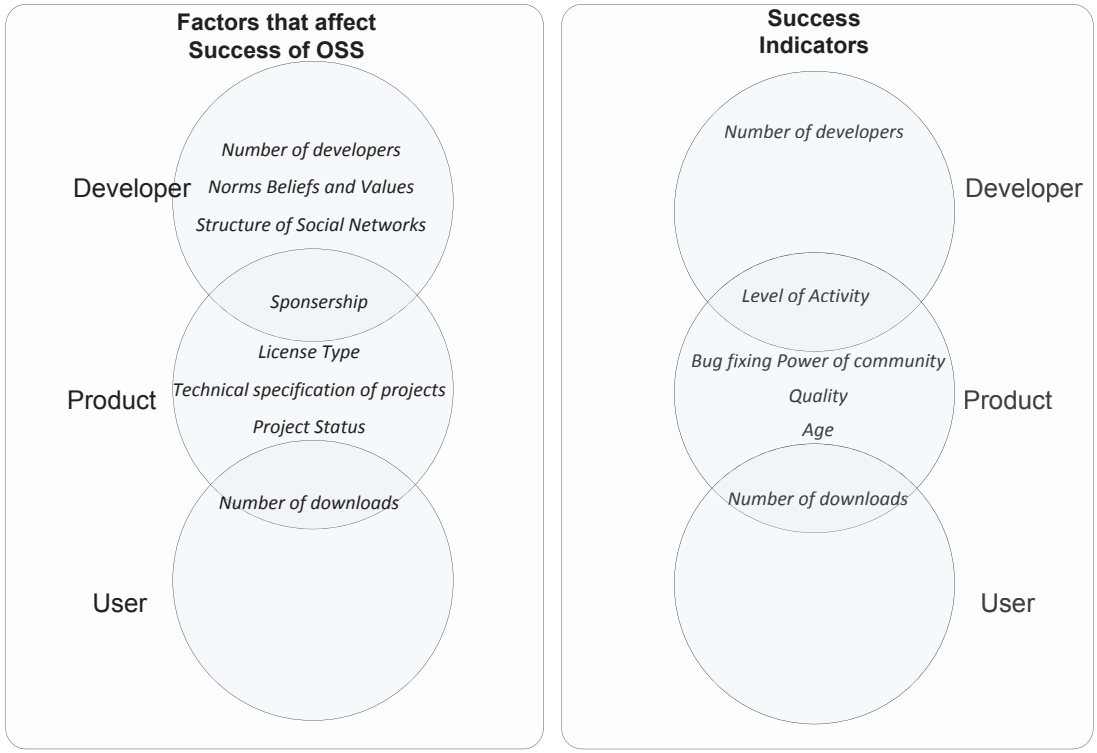

Fig 3 Taxonomy of variables in success model for OSS

VI. Conclusion

Reviewing the related work in the field of OSS success, we observe different measures and factors for success and noticed that different methods are used in research in the field but source of data is mainly repositories of OSS projects such as sourceforge.net and freshmeat.net. We mainly recommend using variety of methods for research in the field and also want to draw attention of potential research to context of OSS development in future research.

Although we have done our best to make our review as complete as possible, but the comprehensiveness of the issue and rapid advances in academic research may cause ignoring some of research. We have also paid attention to initial models of OSS success which sometimes has been changed after validation of model.

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Appendix 1: Articles Included in Review

	Reference	Type	Year	Cited by	Success Definition	Factors Affecting Success	Research Method	Scope
1	[17]	Journal	2011	3	User interest Project Activity Project Effectiveness Project Efficiency Product Quality	-	Review	-
2	[1]	Journal	2009	81	Developer interest (number of developers) Program Activity (activity rank) User interest (number of download)	OSS license Operating System Programming Language Project Status Developer interest, user interest, and project activity until previous time period	Data on sourceforge.net	8627 projects on sourceforge.net between Jan 1999 to Dec 2005
3	[4]	Journal	2009	79	Individual net benefits	Software quality Use User Satisfaction Community service quality	Survey	Linux User Group In Korea
4	[24]	Conference	2009	1	Development activity (number of total tracks) Popularity (subscription and donation)	Communication pattern of project: Project Centrality Project Density Leadership Centrality Project Specific Characteristics: Project complexity Types of license Project age Programming language Target audience	Data on sourceforge.net	126 projects in Sourceforge.net on a period of 13 months.
5	[25]	Journal	2009	1	Number of developers Number of downloads Issue-handing performance.	Trends of success metrics Correlation of success metrics of success	Case Study (Data on sourceforge.net)	4 OSS projects on sourceforge.net
6	[26]	Conference	2009	2	Download	Rank Activity Members Duration	Datamining	5000 most downloaded projects on sourceforge.net
7	[20]	Journal	2009	-	Rank Download Communication activity Participations	Project Sponsorship License type Development Status Technological complements (programming language, operating system, database)	Data on sourceforge.net	174 health projects on sourceforge.net
8	[19]	Journal	2009	0	Number of Producer Number of Consumer	Maturity Stage Developers per project Projects per developers	Data on sourceforge.net	Sourceforge.net

9	[27]	Journal	2007	25	Reaching a stable or mature release	Restrictiveness of license User Type Larger Projects Oldness of project	Data on sourceforge.net	All OSS projects that were hosted on SourceForge.net in December 2004.
10	[28]	Conference	2008	11	Period of activity Size achieved Developers Activity	Entrance to a successful forge	Data on sourceforge.net	Comparing 50 projects on Sourceforge and 50 on Debian
11	[29]	Conference	2007	2	The pattern of download (Study of 6 different patterns)	-	Data on sourceforge.net	16 projects on Sourceforge.net
12	[30]	Conference	2007	19	Making useful software	-	Interview + study of projects on sourceforge.net	60 projects on sourceforge.net
13	[31]	Journal	2006	141	Team Effectiveness: Team size Team effort Task Completion	Communication Quality Trust Adherence to norms Adherence to beliefs Adherence to values	Survey + Data on OSS projects	Survey of 18, 16 and 51 administrators of sourceforge.net's projects. (3 stages)
14	[32]	Journal	2006	104	Commercial success (number of downloads) Technical Success (number of CVSs)	Network embeddedness: The rule of Social Capital (relations among developers) The importance of project managers' location	Data on sourceforge.net	108 projects on sourceforge.net with 490 developers
15	[33]	Journal	2006	68	Developer motivation (number of subscription – developer activity) User interest (number of subscriptions to project)	License restrictiveness Organizational support	Data on Freshmeat.net	Freshmeat.net And homepage of projects
16	[34]	Journal	2006	13	Perceived effectiveness Number of developers Task completion	Team climate (Trust and Ideology) Development Stage	Data on sourceforge.net	67 projects on sourceforge.net
17	[5]	Conference	2006	7	Number of downloads	Rank of the project (verifying the Zipf's law in this regard)	Data on sourceforge.net	41608 projects on sourceforge.net
18	[21]	Journal	2006	93	Number of developers Community size	Download count Age Bug fixing time	Survey + Literature review + Data on sourceforge.net	122 projects on Sourceforge.net
19	[35]	Conference	2004	26	Creation of quality software Continued team work Team member satisfaction	Challenging but obtainable goals Rewarding members for contribution Access outside expertise Projects that gather information about the situation and alternative actions Different rules for members Higher level of effort by members	Theory development	-

						More members More active users More knowledgeable members --- Less dependencies in tasks Manage of dependencies --- Highly developed shared mental models Tasks that align members Higher levels of socialization, conversation and narration		
20	[36]	Conference	2005	39	Number of downloads	Process maturity (availability of: Version control (like CVS) Mailing list Documentation Systematic testing Portability)	Data on sourceforge.net	80 projects on Sourceforge.net
21	[37]	Conference	2004	18	Age Number of closed bugs Subjective feelings of members	Coordination Safeguarding of exchanges --- Restricted Access to members Collective Sanctions Reputation	Survey	Survey of 318 developers
22	[38]	Conference	2004	55	Number of community Project activity Bug fixing time Number of download	Relationship among success factors	Survey + Data on sourceforge.net	122 projects on Sourceforge.net
23	[23]	Conference	2003	155	Number of developers Level of activity of developers Cycle time (Time to close bugs) Employment opportunity Individual Reputation Knowledge Creation	System and information quality: Code quality Documentation quality --- User satisfaction: User ratings Opinions on mailing lists User surveys --- Use: Number of users Downloads Inclusion in distributions Popularity or views of information page Package dependencies Reuse of code	Theory development + Survey	-
24	[39]	Conference	202	116	User interest (number of downloads) Project development status	Using more common programming language Project audience Project topic Number of developers Highly ranked administrators Higher activity	Data on sourceforge.net	7477 projects on Sourceforge.net