

# OSS Project Success: From Internal Dynamics to External Impact<sup>1</sup>

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## Abstract

*Success in open source software (OSS) development has been viewed in many different ways. This paper examines the relationship between success in terms of the development efforts devoted to an OSS project and success in terms of the acceptance of the software by stakeholders beyond the immediate development group. Research has discussed the importance of communication, norms, and other factors related to the dynamics of work within open source software development groups. The model proposed here suggests a positioning of these internal dynamics in a larger nomological net explaining variation in the success of OSS efforts.*

## 1. Introduction

Research has assessed the output of individual OSS projects and examined how dynamics within OSS projects influence the development of the software product (e.g., [21, 25]). In addition, several studies have taken a higher level view and sought explanations for the phenomenon of OSS and an understanding of the wider OSS community (e.g., [17, 18]). Building on this work, this paper suggests positioning what has been learned about OSS development in a wider framework targeted at understanding the impact of OSS on users. A main contention of the paper is that as OSS diffuses across a broader set of users and types of uses, it becomes important to understand how the individual characteristics and internal dynamics of OSS projects influence the eventual impact that the software produced in those projects has on users.

The paper first suggests a multifaceted understanding of success in OSS from both a development perspective (i.e., success in terms of attracting input and producing output at the project level) and a usage perspective (i.e., success in terms of user interest, adoption, and impact related to specific OSS projects). Section three then

summarizes the proposed theoretical model and the high level propositions it encompasses. The final section discusses further development of the model, limitations, and implications.

## 2. Conceptualizing OSS Success

OSS development has been conceptualized as a phenomenon at the community [1], organizational [19] and team/group level [21]. While recognizing the utility of these different levels of analysis, the focus of this paper is limited to discussing OSS success at the project level. Thus dimensions of and antecedents to success discussed below are conceptualized at the level of the team working on a project, the project itself, or the users of a specific project.

Some success indicators applied to commercial software projects – e.g., being on-time, on-budget, and meeting specifications – may not be readily applied in the OSS setting. In this setting, there may be no a priori budget, timeline, or set of specifications [25]. Other evaluation criteria applied to projects in the IS and software engineering literatures are more applicable. These include system quality, information quality, system usage, user satisfaction, and system impact on users and organizations [5].

In addition to conceptualizations of success that may be applied from closely related settings, there are some kinds of success uniquely relevant in OSS development. Because OSS often depends on volunteer labor, the extent to which a project attracts, retains, and motivates developers is an important aspect of success [21]. This kind of success may be indicated by such factors as the number of developers involved, the level of project activity (e.g., bug fixes, patches provided, new features and software releases), or project development status (e.g., alpha testing, beta testing, production, etc) [3, 27].

The model depicted in figure 1 includes two broad types of OSS success, labeled *development success* and *usage success*. Development success is proposed to

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consist of success in attracting input to the project and success in producing project output. The former might be indicated, for example, by the number of contributions made to the code repository while the latter might be indicated by an assessment of the quality of the software release. Usage success is composed of user interest, which might be indicated by a user downloading project files, and also user impact, which might be indicated by performance changes that result from use of the software.

### 3. Antecedents to OSS Success

Research suggests many potential factors that may influence both development and usage success. For the purpose of this paper these factors are grouped into three categories: those associated with the development team (Team Factors), those associated with the product of the team (Project Factors), and those associated with users of the product (User Factors). The remainder of this paper presents propositions about the main mechanisms by which these sets of factors may influence OSS success both in terms of development and usage.

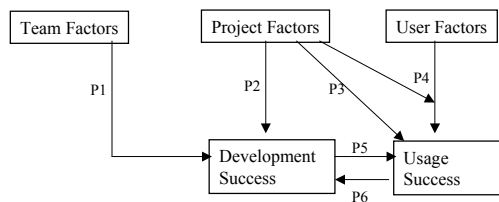


Figure 1: A general framework of OSS success

#### 3.1 Impact of Team Factors

In many ways OSS teams are like the virtual teams studied in the IS literature. For example, they generally use the Internet as their main means of communication, and they may have widely distributed members. Among the team factors argued to be important in prior work, trust, communication, and culture have been suggested to play especially important roles in OSS [18, 28]. Because they have been the focus of prior work, these three team factors are discussed as exemplars below.

*Trust.* Ljungberg ([18]:215) states that “(Open source) could be seen as a virtual organization, but where trust has replaced law in regulating relations.” This view is consistent with much of the management and virtual teams literature, which has argued that trust is closely linked to performance outcomes (e.g., [15]). When affective trust exists, sensitivity to the personal and work-related needs of other group members is high [20], leading to higher levels of responsiveness in helping other team members. Affective trust has been shown to have a

positive impact on organizational citizenship behavior among managers and peers [20]. Further, affective trust is persistent, leading to the discounting of events that are contrary to ongoing harmony [14]. In the OSS context, for example, a contributor whose code is not accepted into a new release in one instance may feel rejected and choose to leave the group by ceasing to contribute. However, if affective trust is high, negative events such as this are more likely to be attributed to situational factors and not result in a reduction of commitment to the project.

*Communication.* Studies of commercial software design efforts have found that high performing virtual teams significantly “outcommunicated” low performing virtual teams [22]. Previous work on communication in virtual teams implies at least two distinct types of communication may be important: social communication, in which team members discuss things other than the project (e.g., their hobbies, families, and weekend plans) and task relevant communication, which is characterized by the extent to which the communication is perceived to be useful (e.g., timely and helpful with regard to the project) [15, 36]. Social communication enhances identification with the team and commitment to the team while task communication is required to complete and coordinate work. Thus social communication may influence retention of developers and therefore impact input while task communication facilitates the coordination and combination of input to produce high quality outputs.

*Culture.* Of the many antecedents to success suggested in the virtual teams literature, culture has received the widest acknowledgement as a factor especially important in OSS [1, 2, 19]. Ideology, a key component of culture, is defined as “shared, relatively coherently interrelated sets of emotionally charged beliefs, values, and norms that bind some people together and help them make sense of their worlds” [30]. Beliefs refer to understandings of causal relationships, values refer to preferences for some behaviors or outcomes over others, and norms refer to behavioral expectations.

Though culture is by definition shared, it may vary across subgroups [12, 13]. Open source developers have often been said to constitute a community, identifiable by its common culture [1]. At the same time, subgroups are formed around projects within that community, and such subgroups may vary in the extent to which they conform to the overarching community ideology. Indeed, Ljungberg ([18]: 210) suggests that ideology varies widely across OSS developers: “At one end of the spectrum there is great zeal...at the other end there is no big deal about the ideology.”

In general, the existence of a shared ideology in a workgroup is thought to facilitate group efforts. Shared values can lead to better mobilization of group members

towards directed ends by connecting group goals to moral imperatives, and personal commitment may be created by increasing the salience of collective identities and values and linking behaviors to these identities and values [26]. Ideological commitment serves as a particularly effective control in distributed contexts where close supervision is not feasible and every type of contingency may not be easily accounted for and codified in contractual terms [23].

The OSS ideology in particular seems designed to facilitate project work. Main components of the OSS ideology as including values related to sharing and helping others, learning through participation, and protecting group member contributions [28]. Thus the extent to which project members subscribe to the common open source ideology may have positive effects on development success by increasing group commitment and acting as a control mechanism.

*Summary.* The brief discussion above is meant to show that team factors discussed in prior work – trust, communication, culture – may all work through similar mechanisms to influence the success of OSS development efforts. The proposition below is intended to imply that other team factors – for example, leadership style or group member heterogeneity – might be fruitfully examined by considering their impact on these same mechanisms.

**Proposition 1: Team factors that enhance developer identification with and commitment to a project attract and retain more developer input and facilitate the successful conversion of that input into output, leading to greater overall development success.**

### 3.2 Impact of Project Factors

Contrary to some popular conceptions of OSS development as drawing from an infinite pool of talent (e.g., [31]), OSS work requires specific skills and there is a limited pool of people with the knowledge and motivation to be able to productively contribute, leading to potential competition among projects to attract developer efforts. For example, [16] cites the Orbiten Free Software Survey [8], which indicates that the 100 most prolific OSS contributors contribute to 1,886 distinct projects, a contributor to project ratio of approximately 1 to 19. Other analyses [6, 17] also show that a relative few individuals make most contributions, while most contributors make only a single contribution. Thus given the voluntary nature of most OSS participation, development success may depend in large part on the extent to which productive developers are motivated to contribute to one project versus another.

With regard to motivation, researchers have suggested that OSS contributors find programming intrinsically

motivating, deriving feelings of competence and self-determination from the activity itself or from helping others [3, 11]; that they contribute to satisfy their personal needs for software [11, 24, 34]; and that programmers contribute to enhance their skills and reputations [16], possibly with the expectation of future returns [4, 11, 17]. Future returns might be derived because participation in OSS both allows contributors to increase their human capital (e.g. by honing their skills), and it allows them to advertise their skills thereby enhancing their reputations and their prospects for paid development work [10, 11, 17]. Given that projects compete for members and that participation in a project is largely a function of a developer's motivation, the model suggests that a major influence on development success will be the relationship between project characteristics and developer motivations. Potential developers will judge the opportunities for skill development, potential utility, and possible reputational benefits based on characteristics of the project such as the license used, the problem domain addressed, or the programming language used.

**Proposition 2: The greater the alignment between project factors and OSS developer motivations the greater will be the development success of the project.**

Project factors may also be important in determining usage success, as characteristics such as license may be readily observed by potential users. The IS literature on technology acceptance and usage provides a foundation for considering antecedents to OSS user interest and impact. This literature has overwhelmingly supported the idea that perceptions of utilitarian value (perceived usefulness) and perceptions of required effort (perceived ease of use) are key determinants of behavioral intention to use and actual use of technology [29, 33].

Research in the marketing literature has demonstrated that perceptions of value, which in this setting would result from usefulness and ease of use, may be developed from individuals' use of extrinsic cues in the formation of product quality and cost perceptions [7]. Using affect-referral, customers simplify their decision making process by basing their judgments on summary information (e.g., brand attitudes) rather than on product attribute information [35, 37]. In the OSS context, although code is available for inspection, users may not have the necessary background knowledge to evaluate the inner workings and features of a software program before they install it, or even if they do have the requisite skill, they may seek to minimize the cognitive effort involved in evaluation by relying on more easily interpreted cues. Project characteristics such as organizational affiliation and license may be viewed as salient extrinsic cues for evaluating the usefulness and ease of use of OSS projects.

**Proposition 3: Project characteristics that are perceived to indicate high levels of usefulness and ease of use of the software will have a positive impact on user interest and adoption.**

### 3.3 Impact of User Factors

The least explored areas of OSS success included in the model are user impact and the role of user factors. When contemplating adoption of a new software package, users must consider many issues including integration with current technology infrastructure and future requirements for maintenance. Thus users may vary in their ability to use and benefit from OSS based on factors such as their technical expertise. However, the importance of such factors will depend heavily on the nature of the software being considered. While integration with current technology may be crucial for the organization user contemplating adoption of an OSS software development tool, it may be irrelevant for the individual user considering downloading a new OSS game. Thus the proposition represented in the research model is derived from contingency theory [9, 32], which suggests that outcomes depend on the fit, or lack of fit, among organizational and environmental factors. The impact (positive or negative) that OSS adoption may have on users will depend on the extent to which characteristics of the project “fit” with characteristics of the user.

**Proposition 4: The extent to which project characteristics are aligned with user factors will have a positive impact on usage success by both increasing user interest and increasing the likelihood of positive impact from adoption.**

### 3.4 Relationship between Development and Usage Success

Above, it has been assumed that in order for a project to be successful in creating output, it must first attract development input. Similarly, project output may be expected to affect user interest such that more active projects are also more popular, based on the idea that the quantity and quality of output are critical to perceived usefulness. The model also suggests a feedback effect from usage success to development success that is derived from a consideration of the motivations of OSS developers. The greater the user interest in a project, the wider the audience for individual contributions and therefore the more visible the efforts of contributors. Hence there may be greater potential reputation benefits from working on more popular projects [17], and we might expect such projects to attract more activity from developers. Further, an active user base will generate defect reports and support requests [21], providing greater

opportunities for developers to hone their skills on a variety of tasks and thereby stimulating more development input.

**Proposition 5: OSS development success will increase the perceived usefulness of an OSS product and thereby have a positive effect on usage success.**

**Proposition 6: OSS usage success will enhance the motivation of developers to contribute to a project and thereby have a positive effect on development success.**

## 4. Conclusion

This paper has presented a model of how developer, project, and user factors may influence the success of OSS projects both in terms of attracting input and generating output (development success) and also in terms of attracting user interest and providing benefits to users (usage success). As depicted in figure 1, the research reviewed above indicates three important categories of influences on OSS success, labeled team factors, project factors, and user factors. Propositions outline the mechanisms by which these factors may influence OSS success. The model has several limitations, for example there may be other categories of factors that are omitted but have important impacts on success (e.g., environmental factors such as the current economic climate in an industry could impact the success of OSS products targeted toward that industry). Such limitations aside, the model is presented in the hope that it may encourage researchers to more deeply examine questions related to the impact that OSS may have on the user community and how the internal dynamics in projects, here encompassed in team factors, may have effects on the ultimate external acceptance and impact of the software.

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