Measuring open source software success[☆]

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Abstract

Since the mid-1990s, there has been a surge of interest among academics and practitioners in open source software (OSS). While there is an abundance of literature on OSS, most studies on OSS success are either qualitative or exploratory in nature. To identify the factors that influence OSS success and establish generalizability, an empirical study measuring OSS success would enable OSS developers and users to improve OSS usage. In this study, we develop an OSS success model from a previous Information Systems success model incorporating the characteristics of OSS. Using the proposed model, we identify five determinants for OSS success as well as a number of significant relationships among these determinants. Our findings demonstrate that software quality and community service quality have significant effects on user satisfaction. Software quality and user satisfaction, in turn, have significant effects on OSS use. Additionally, OSS use and user satisfaction have significant effects on individual net benefits. This research contributes towards advancing theoretical understanding of OSS success as well as offering OSS practitioners for enhancing OSS success.
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1. Introduction

Since the mid-1990s, there has been a surge of interest among academics and practitioners in open source software (OSS). Fuelling this interest are successful projects including the Mozilla web browser, the Linux operating system, the Apache web server, and to a lesser extent, the PHP and Perl programming languages, as well as the MySQL database. OSS has drawn the attention of users and developers because of its economic benefits. Developers have additional reasons for developing and using OSS because the project is a good learning opportunity [1,2]. Many developers who participate in an OSS project consider it good experience for their career management [3].

While there have been successful OSS projects, mostly with backend servers and Internet-related software, the number of failed or dormant OSS projects is also notable. In fact, according to the popular open source portal, SourceForge (http://sourceforge.net/), most OSS projects have ended in failure: 58% do not move beyond the alpha developmental stage, 22% remain in the planning phase, 17% remain in the pre-alpha phase, and some become inactive.[1] Similar results have been reported by the World Bank

[1] The statistics of Open Source projects was obtained in March 2005.

study [4] which cites a failure rate of more than 50% for OSS projects.

Little is known about how to enhance the success rate of OSS. Studies on OSS success thus far have been exploratory or qualitative in nature. As the initial step in enhancing the success rate of OSS, this study aims to develop a model measuring OSS success. Toward that end, we review previous information system (IS) success models and adapt them by incorporating characteristics of OSS. We seek to answer two research questions: (1) What are the factors determining OSS success? (2) How do these factors influence each other?

The results of this study may help advance theories on IS success and offer practical insights for OSS users. For practitioners, a better understanding of OSS success can lead to better management and more accurate identification of potentially successful OSS. For academic researchers, the success factors of OSS identified in this study can be generalized and applied to research on the effectiveness of virtual or distributed communities and work groups. This study can also provide lessons and directions for future empirical research on OSS success.

The rest of the paper is organized as follows: Section 2 presents the theoretical framework of our research, followed by the research model and hypotheses in Section 3. We describe our research methodology in Section 4, and present empirical results in Section 5. Section 6 discusses findings and limitations, followed by the conclusion in Section 7.

2. Theoretical framework

There is an abundance of literature on OSS, and some studies on OSS have also considered, to some extent, OSS success. However, literature on OSS success is largely qualitative [5–8] or exploratory [9,10] in nature. So far, no empirical model has been established for measuring OSS success. Instead, attempts have been made in using a well-known IS success model as the basis for measuring OSS success. Crowston et al. [11], for example, came quite close to measuring OSS success by developing a model based on the DeLone and McLean [12] model of IS success and identifying a range of measures that could be used for assessing the success of OSS projects. They do not, however, validate their study with empirical research. Empirical research is necessary to validate their measures in the OSS context.

Seddon [13] proposed an extended and redesigned version of DeLone and McLean's [12] model by including perceived usefulness, individual net benefits, and societal net benefits in their model. Their main objection to DeLone and McLean's [12] model was ambiguity in

defining the 'use' construct, which entails three different meanings. One meaning specifies the benefits from use, a dependent variable in a variance model of future use, as events leading to an individual or organizational impact. However, these criticisms were considered unjustifiable by later studies (e.g., [14]).

DeLone and McLean [15] later updated their original model [12] to include service quality. DeLone and McLean [15] argued that the update was necessary to account for dramatic changes in IS practice, especially with the advent and explosive growth of e-commerce. The updated DeLone and McLean [15] model, as shown in Fig. 1, is a mixed process and causal model. The updated model assumes that system quality, information quality, and service quality, both individually and jointly, affect user satisfaction and use. The model also suggests user satisfaction and use to be reciprocally interdependent, and presumes them to be direct antecedents of individual impact. DeLone and McLean [12] characterize system quality as the desired characteristics of the information system itself, and information quality as the desired characteristics of the information product. While there are numerous empirical studies (e.g., [16]) that test the DeLone and McLean [12] model, studies testing their updated model [15] are relatively few in number (e.g., [14]).

For measuring OSS success, the DeLone and McLean [15] IS success model would be more suitable compared to the work of Seddon et al. [17] for two reasons. First, the Seddon et al. [17] model classifies organizational benefits and societal benefits as two of its core components, thus suggesting that the model is more suitable at the firm or society level. As those using OSS are mainly individual users, DeLone and McLean's [15] model, which characterizes both individual impact and organizational impact, would be more suitable for empirical testing with regard to individual users [18]. Second, previous studies [12,19] have considered usefulness a component of IS quality. Measures extracted from existing research on OSS success [11,20,21] could easily be incorporated into the updated DeLone and McLean [15] model, making it the most appropriate reference model for our study.

Having selected DeLone and McLean's [15] IS success model, we adapt it for the purpose of our study by incorporating the context and characteristics of OSS. Table 1 summarizes how our proposed model is adapted from the DeLone and McLean [15] model and how it differs from two other established IS success models. Comparisons are discussed in detail below.

This study focuses on the success of OSS (e.g., Linux operating system), not on OSS-based application
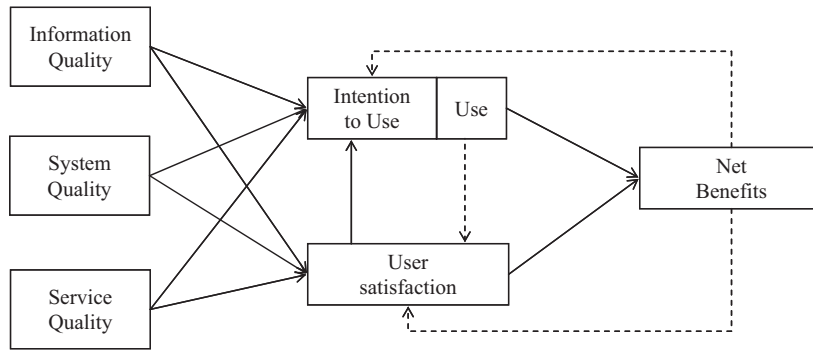
Fig. 1. Updated DeLone and McLean [15] IS success model.

Table 1
Comparison of IS success models

DeLone and McLean [12]	Seddon [13]	DeLone and McLean [15]	OSS success model of this study
System quality	System quality	System quality	Software quality
Information quality	Information quality	Information quality	–
Use	Perceived usefulness	Use (intention to use)	Use
User satisfaction	User satisfaction	User satisfaction	User satisfaction
Individual impacts	Individual net benefits	Net benefits	Individual net benefits
Organizational impacts	Organizational net benefits	–	–
–	Societal net benefits	–	–
–	–	Service quality	Community service quality

systems (e.g., Linux-based sales system). OSS itself is not an application system and does not produce or process information as an output. DeLone and McLean [12] characterize information quality as the accuracy, meaningfulness, and timeliness of information produced by a system under consideration. While information quality may be an important aspect of OSS-based application systems, our target OSS (i.e., Linux operating system) is not designed to produce any information. For this reason, we drop the information quality construct from the DeLone and McLean [15] IS success model in measuring the success of OSS. Similarly, OSS is characterized by its software aspect. For this reason, we change DeLone and Mclean's [15] 'system quality' construct to 'software quality'.

The term 'service quality' in DeLone and McLean's [15] model is also relevant to this study. Service quality in the IS success model measures the effectiveness of services provided by the IS department in organizational settings. In the context of OSS, service quality can be interpreted as some form of technical support that comes primarily from peer users, i.e., the OSS development community [2]. Hence, we refer to *service quality* as *community service quality* in OSS context.

The users need support, cooperation, and assistance during both the development and post-development phases. Subsequent production of newer software versions following initial installation such as upgrades, patches, and new releases may also be considered a form of support. The OSS development community can play a role similar to that of the IS department in providing services, because the OSS development community develops and modifies OSS and provides additional services including information provisions to its OSS users. When applied within the OSS context, therefore, *community service quality* can be defined as *an individual's perception about the reliability, responsiveness, assurance, and empathy of the service provided by the OSS development community*.

Next, we measure the net benefits of OSS in terms of net benefits to individual OSS users. By using OSS, individuals would derive benefits that include improved performance. We classify these benefits as individual net benefits. Finally, the DeLone and McLean [15] model is a process model, which also considers feedback loops from use to user satisfaction, as well as feedback loops from net benefits, intention to use, and user satisfaction. Our study, however, is cross-sectional in nature

and does not measure more than a single usage of the OSS; therefore, feedback loops have been omitted from our study.

3. Research model and hypotheses

Based on the identified determinants for OSS success and the updated IS success model of DeLone and McLean [15], we propose the OSS success model in Fig. 2 as our research model.

DeLone and McLean [15] hypothesize that the greater the system quality (software quality in this study) and service quality (community service support in this study), the more the system is used. At a general level, there is considerable empirical research supporting the influence of system quality on IS Use (OSS use in this study). The technology acceptance model (TAM) [4] predicts that perceived ease and usefulness, two key aspects of system quality [12], have significant effects on IS use. Previous research has shown that system quality influences IS use [22,23]. Moreover, Pitt et al. [24] as well as DeLone and McLean [15] suggested that service quality and system quality influence IS use. These relationships may also be applicable within the OSS context. Therefore, we hypothesize:

H1: *Software quality has a positive effect on OSS use.*
H2: *Community service quality has a positive effect on OSS use.*

Following previous research [25], this study regards user satisfaction as an emotional response. Regarding the relationship between software quality and user satisfaction, studies [26–30] have tested the direct association between these two characteristics and determined the association to be statistically significant. Seddon and Kiew [28] also found significant effects of system quality on user satisfaction. Additionally, there is considerable evidence that service quality has a significant influence on individual satisfaction. Many researchers (e.g., [31–33]) have characterized service quality as an antecedent to satisfaction. Studies of Bitner et al. [34] and Lee and Yoo [35] regard service quality as an overall evaluation of the service under consideration and customer satisfaction as a result of specific service transactions. These relationships may also be applicable within the OSS context. Therefore, we hypothesize:

H3: *Software quality has a positive effect on user satisfaction.*
H4: *Community service quality has a positive effect on user satisfaction.*

Bolton and Lemon [36] empirically tested the relationship between satisfaction and system usage. According to expectation–disconfirmation theory, those users who feel satisfied with their system continue to use the IS. Satisfaction is an affect, captured as a positive (satisfied), indifferent, or negative (dissatisfied) feeling [25]. Affect (as attitude) has been theorized and validated in TAM based studies as an important indicator of intentions concerning IS use (e.g., [37–39]). The relationship between user satisfaction and IS usage has received wide conceptual and empirical support in the literature (e.g., [25,40]). This relationship may also be applicable within the OSS context. Hence, we hypothesize:

H5: *User satisfaction has a positive effect on OSS use.*

Regarding individual net benefits, DeLone and McLean [15] explained that net benefits (i.e., impacts) are measured in terms of job and decision-making performance. Net benefits measure the results of IS usage. Net benefits are thus considered to be a judgment rather than a belief. According to DeLone and McLean [15], certain net benefits will occur as a result of IS usage and IS user satisfaction. In general terms, it can be argued that if the user is satisfied with the IS, the IS will have an impact on the user's performance. The effect of user satisfaction (emotional response) on net benefits (judgment) can be explained by the affect-as-information model [41]. According to the affect-as-information model, people rely on their actual feelings (or emotional response) to form overall judgments. This is because feelings are influential not just in determining valuable judgmental information, but are also regarded as representatives of the target. Gatian [42] found close associations between user satisfaction and decision performance, as well as between user satisfaction and efficiency. This relationship may also be applicable within the OSS context. Hence, we hypothesize:

H6: *User satisfaction has a positive effect on individual net benefits.*

Similarly, it can be argued that the more a user uses a system, the greater the impact will be on his performance [14]. Srinivasan [23] reports that the indicators of system use (connection time and user type) are significantly associated with the problem solving capabilities of the user. Livari [43] found CASE usage to have a significant effect on the productivity of individual users (system developers) and on the quality of their products. Similarly, Leidner [44] found that IS use (e.g., executive information systems) has a significant effect
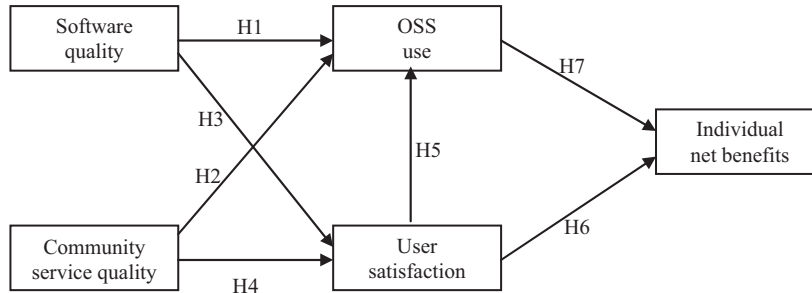
Fig. 2. Research model.

on task performance (e.g., efficiency in decision making). This relationship may also be applicable within the OSS context. Hence, we hypothesize:

H7: *OSS use has a positive effect on individual net benefits.*

4. Research methodology

4.1. Instrument development

To test the hypotheses, we conducted surveys on the Linux User Group and the online Linux Open Source community. We selected Linux as the OSS in this study for data collection and testing. We developed the survey instrument by adopting existing validated instruments wherever possible. Measurement items for OSS use and Individual satisfaction were adopted from Cheung et al. [45] and McKinney et al. [19]. Measurement items for software quality were adopted from Rai et al. [18] and DeLone and McLean [12]. Service quality of the OSS development community (i.e., community service quality) consists of five correlated dimensions: responsiveness, assurance, reliability, empathy, and tangibles. However, the OSS development community is a type of virtual community with no tangible dimension. This study thus measures overall community service quality by selecting the most representative measurement items across the four dimensions. Measurement items are adapted from the SERVQUAL scale [24] as recommended by DeLone and McLean [15]. Questions were anchored on a seven-point Likert scale (1 = strongly disagree, 7 = strongly agree). To enhance content reliability, the list of categorized measures was subsequently screened by an academic in charge of an OSS student interest group.[2] We also judged construct validity by deter-

mining convergent and discriminant validity based on the level of consistency within the categorization of items [46]. The final instrument used for data collection is shown in Table 2.

4.2. Data collection

Once we determined that the instrument was reliable with high validity, we carried out the survey. To avoid sending out large email messages, copies of the questionnaire in three different file formats (MS Word, OpenOffice, and plain text) were uploaded to a Web server for respondents to download, complete, and then email to us. We provided the Universal Resource Locator (URL) to the files in our emails and in postings to mailing lists and groups. We also administered the questionnaire in face-to-face survey sessions.

The target populations for the study were the users and developers of OSS over the Internet. We collected data from the Linux Kernel project, the Linux User Group, a university Linux user group, student users of the MySQL database, the computing faculty of a large university, and external participants through informal personal contacts. The questionnaire was prefaced by a cover letter stating the purpose of the survey, instructions, and an assurance of confidentiality and anonymity. To improve response rates, 5000 Korean Won (approximately $5 US) were given to each respondent.

We obtained a total of 157 responses. After accounting for missing data, we were left with 145 valid responses. We tested for any statistically significant differences between the group of respondents who attended the face-to-face survey sessions and those who responded via email by comparing the means of the two samples by way of a t-test. The t-test revealed no significant differences between the groups in terms of age, computer experience, or OSS usage experience. Table 3 summarizes characteristics of the respondents.

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[2] The academic had prior experience in OSS development and headed an OSS user group.

Table 2
Measurement instrument

Variable	Item	Description	Reference
Software quality (SWQ)	SWQ1	[OSS] is user friendly	Rai et al. [18]
	SWQ2	[OSS] is easy to use	DeLone and McLean [12]
	SWQ3	[OSS] has useful functions	
User satisfaction (SAT)	SAT1	I am satisfied with the use of [OSS]	McKinney et al. [19]
	SAT2	I am pleased with the use of [OSS]	
	SAT3	I am content with the use of [OSS]	
	SAT4	I am delighted with the use of [OSS]	
Community service quality	CSQ1	[OSS] development community shows sincere interests in solving any reported bugs or problems	Pitt et al. [24]
(CSQ)	CSQ 2	[OSS] development community members have the knowledge to do their job well	
	CSQ 3	[OSS] development community is dependable	
	CSQ 4	[OSS] development community gives prompt information and service to users	
	CSQ 5	[OSS] development community is always willing to help users	
	CSQ 6	[OSS] development community understands the specific needs of its users	
OSS use (USE)	USE1	I use [OSS] very frequently (many times per month)	Cheung et al. [45]
	USE2	I use [OSS] very intensively (many hours per month)	
	USE3	I use [OSS] for a variety of tasks (reports, projects, decision making, etc.)	
	USE4	Overall, I use [OSS] a lot	
Individual net benefits (NBF)	NBF1	Using [OSS] teaches me a lot	DeLone and McLean [12]
	NBF2	Using [OSS] improves my skills and knowledge	
	NBF3	Using [OSS] enables me to accomplish my tasks more quickly	
	NBF4	Using [OSS] improves my task performance	
	NBF5	Using [OSS] improves my productivity	
	NBF6	Using [OSS] increases the quality of output of my task	
	NBF7	Overall, using [OSS] is of benefit to me	

5. Data analysis and results

Given the newly adapted model and measures, a confirmatory covariance based analysis (CBA), such as LISREL, was not suitable. PLS is suitable for our study for several reasons. First, PLS can test the psychometric properties of the indices and provide better evidence for the existence of relationships [47]. Secondly, the investigation of this model is exploratory in nature rather than confirmatory. Thirdly, PLS has less stringent standards regarding sample size, distribution parameters, and levels of correlation between variables. For this study, PLS-Graph version 3.00 [48] and the bootstrap re-sampling method were used to assess the measurement and structural models.

We then performed data analysis in accordance with a two-stage methodology [49] using PLS. The first step in the data analysis was to establish the convergent and discriminant validity of constructs using the measurement model. The second step was to test the structural model.

5.1. Test of measurement model

We tested the reliability and validity of the measurement model (Table 4). A common method for testing

Table 3
Respondent characteristics

Demographic variable	Item	Frequency	Percentage	Mean	SD
Age (years)	$\leqslant 16$	1	1	28.12	5.24
	16–25	42	29		
	26–35	89	61		
	36–45	10	7		
	> 45	0	0		
	Not answered	3	2		
Gender	Male	120	83	–	–
	Female	24	17		
	Not answered	1	1		
Computer experience (years)	$\leqslant 1$ year	0	0	12.75	4.62
	1–3 years	3	2		
	3–6 years	8	6		
	6–9 years	16	11		
	> 9 years	116	80		
	Not answered	2	1		
Usage of OSS (years)	$\leqslant 1$ year	25	17	4.65	3.54
	1–2 years	28	19		
	2–3 years	7	5		
	3–4 years	13	9		
	4–5 years	18	12		
	>5 years	51	35		
	Not answered	3	2		

reliability is Cronbach's α assessment. Hair et al. [50] suggested that a generally accepted lower limit for Cronbach's alpha is 0.70, although that may decrease to 0.60 in exploratory research. Cronbach α values for all constructs exceeded 0.85 in our study. For convergent validity, we conducted two tests following the study of Fornell and Larcker [51], a composite reliability (CR) test and average variance extracted (AVE) test. The CR for each construct must be greater than 0.7 and the AVE for each construct must exceed 0.5 [51]. Falk and Miller [52] suggested that the factor loading of each indicator should be greater than 0.55. As shown in Table 4, the standardized path loadings for all our questions were statistically significant and greater than 0.55. The composite reliability for all constructs exceeded 0.7 and the AVE extracted for all constructs exceeded 0.5. The Cronbach α value for all constructs also exceeded 0.7. Hence, the questions used in this study had convergent validity.

Next, we assessed discriminant validity by comparing the square root of the AVE for each construct with correlations between that construct and other constructs [51]. As shown in Table 5, the square root of the AVE for each construct exceeded correlations between that construct and other constructs. Hence, the questions used in our study had discriminant validity.

5.2. Test of structural model

We tested our hypotheses using the PLS-Graph (Fig. 3). Applying the bootstrapping technique, we calculated the corresponding t-values for each path in order to assess the significance of the path estimates. Path coefficients and significances are reported in Fig. 3. Software quality (H3) and community service quality (H4) had significant influences on user satisfaction, explaining a 54% variance in user satisfaction. Software quality (H1) and user satisfaction (H5) had significant influences on OSS use with 28% variance. Both OSS use (H7) and user satisfaction (H6) significantly influenced individual net benefits, with 63% variance. Hence, six hypotheses (H1, H3, H4, H5, H6, and H7) were supported while one hypothesis (H2) was not supported.

Since the correlations among the variables were high and significant (Table 6), the non-significance of some hypotheses may be due to collinearity among constructs. Highly collinear variables can substantially distort testing results. The most widely used approach for detecting collinearity is to measure variance inflation factors (VIF) and the condition numbers [53]. In this approach, VIF values and condition indices were extracted. A maximum VIF of greater than ten signals of harmful

Table 4
Results of reliability and validity tests

Item	Factor loading	AVE	CR	Cronbach α
SWQ1	0.852	0.771	0.910	0.85
SWQ2	0.922			
SWQ3	0.860			
CSQ1	0.769	0.686	0.929	0.906
CSQ2	0.817			
CSQ3	0.857			
CSQ4	0.847			
CSQ5	0.835			
CSQ6	0.841			
USE1	0.698	0.683	0.895	0.936
USE2	0.739			
USE3	0.904			
USE4	0.939			
SAT1	0.900	0.838	0.954	0.934
SAT2	0.914			
SAT3	0.923			
SAT4	0.924			
NBF1	0.838	0.803	0.966	0.959
NBF2	0.880			
NBF3	0.887			
NBF4	0.912			
NBF5	0.922			
NBF6	0.916			
NBF7	0.914			

Table 5
Correlation table

Construct	Mean (S.D.)	SWQ	CSQ	USE	SAT	NBF
SWQ	3.93 (1.32)	**0.88**				
CSQ	4.90 (1.08)	0.45	**0.83**			
USE	5.21 (1.58)	0.45	0.33	**0.83**		
SAT	4.90 (1.35)	0.61	0.64	0.50	**0.92**	
NBF	4.64 (1.49)	0.55	0.55	0.56	0.68	**0.90**

Note: The square root of the construct's AVE are shown in the diagonal line.

collinearity and condition indices greater than 30 indicate moderate to strong dependencies. We found that our VIF values were less than ten and that the condition indices were less than 30. Therefore, multi-collinearity was not likely to significantly distort our testing results.

6. Discussion

6.1. Discussion of findings

This study measured OSS success by developing an OSS success model. Based on the DeLone and McLean [15] IS success model, the developed OSS success model consists of software quality and community service quality as determinants of user satisfaction and OSS use, which in turn, determine individual net benefits. We found that user satisfaction was significantly influenced by software quality and community service quality, and that OSS use was significantly influenced by software quality and user satisfaction. Furthermore, we found that OSS use and user satisfaction together significantly influence individual net benefits.

Contrary to the DeLone and McLean [15] IS success model, however, we found that community service quality has no significant effect on OSS use. These results are intriguing, because one might expect that with more
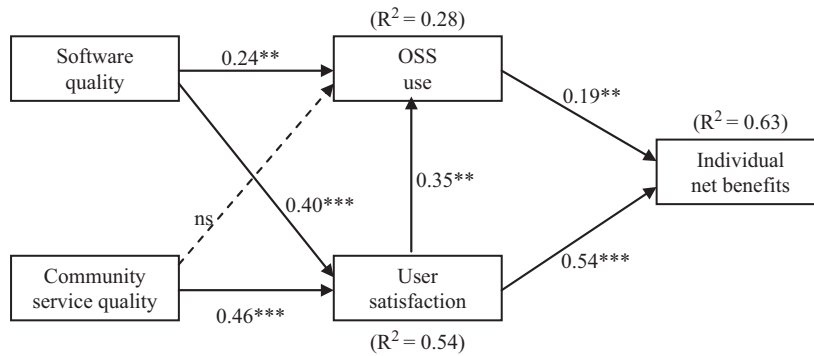
Fig. 3. Testing results (*: $p < 0.05$, **: $p < 0.01$, ***: $p < 0.001$, ns = non-significant).

Table 6
Mediation testing results

	Step 1	Step 2	Step 3
Dependent variable	OSS use	User satisfaction	OSS use
Community service quality	0.302***	0.410***	0.058 (ns)
User satisfaction	–	–	0.381***
R^2	0.091	0.410	0.177

***: $p < 0.001$; ns: insignificant.

support in the OSS community, an individual would have a better chance to use OSS software. This may be because the role of quality determinants on system use varies from context to context [15]. According to DeLone and McLean [15], information quality and system quality are the most important quality components for an individual user, whereas service quality may become the most important variable in an organizational context. To further explore the meditation effect of satisfaction, we conducted meditation test following Baron and Kenney [54]. The results of the test are shown in Table 6. From Table 6, we can infer that user satisfaction fully mediates the effect of community service quality on OSS Use.

Various researchers have applied the IS success model within different contexts. For example, Gable et al. [55] developed a measurement model based on the IS success model for studying Enterprise Systems (ES) success. They proposed satisfaction as a measure of ES success and found system quality, information quality, individual impact, and organizational impact as measures involved in ES success. In agreement with their study, we also found that quality dimensions (software and service) were significant predictors of individual satisfaction. However, Gable et al. [55] omitted ES use, whereas we found OSS use to be an important

predictor of individual net benefits. We argue that use is an important construct because individual impact and organizational impact are based on system usage.

DeLone and McLean [56] tested their IS success model [15] in the e-commerce context. They concluded that the model was flexible and needed to be applied specifically to that context. They did not, however, empirically validate their models. Therefore, it would be difficult to say which dimensions of IS success actually affected IS success. Although an IS success model can be applied to a specific context, empirical validity may still present different results. From our study, community service quality did not influence OSS usage, but its effect was fully mediated by user satisfaction.

Livari [14] tested the IS success model in the context of an actual acceptance of a new IS for the Oulu City Council (mandatory IS). Similar to our findings, the study indicated only system quality and satisfaction to be significant predictors of IS system usage. Contrary to our findings, however, they determined that system usage does not have significant influence on individual impact. Livari [14] argued that the insignificant influence of actual system use on individual impact could be due to the mandatory nature of the system and proposed the need to test this relationship in more voluntary systems. Since OSS is a voluntary system, our results

demonstrating the significant influence of OSS use on individual impact extends Livari's [14] finding to voluntary systems.

Rai et al. [18] tested the IS success model in a quasi-voluntary IS system (student information system of a university). They proposed system dependence as a surrogate for system usage and perceived usefulness as a surrogate for individual impact. Their findings were similar to our findings. In their model, the quality dimension (information quality) also influences IS usage (IS dependence). Since information quality is not relevant to OSS usage, we did not measure its influence.

6.2. Limitations

We acknowledge the limitations of our study. First, the small sample size limits statistical validity, and our findings should be tested on a larger population for generalizability. Second, the proposed model has been tested mostly in Korea, opening the possibility that the results may be idiosyncratic to a particular setting [57,58] discuss the differences between people of Asian countries and US, providing insights into differences that may alter our model due to cultural differences. Replication of this research with subjects from different social, economic and cultural environments is therefore necessary to identify any differences that may exist. Lastly, while Seddon [13] and DeLone and McLean [15] posited that there are feedback effects among some IS success determinants, this study has not considered such effects. As discussed in the previous section, there could be feedback effects between the two key determinants of satisfaction and net benefits. Future studies can consider a longitudinal approach for testing such feedback effects.

6.3. Implications

There are several implications for theory and practice. From the theoretical perspective, this is the first empirical study that measures OSS success by developing an OSS success model. Due to the high failure rate of OSS, little is known on how to enhance the success rate of new applications.[3] To rectify the situation, it is essential to first understand what the main factors determining OSS success are and how these factors influence each other. On this basis, this study has identified five determinants of OSS success and the relationships among them through a literature review of previous IS success models [13,15]; this study also considers the

characteristics of the OSS context. The developed OSS success model provides a rich understanding of the variety of OSS success determinants from five different perspectives. The model further explains and predicts how the determinants of OSS success influence each other.

This study tested the developed OSS success model and examined the significance of the relationships among the OSS success determinants. Specifically, the findings of this study show that usage of OSS is predominantly determined by user satisfaction and software quality. Another key determinant of OSS success, user satisfaction is influenced by software quality and community service quality. Service quality was the newly added determinant in the DeLone and McLean [15] IS success model. Community service quality has a significant effect on user satisfaction, yet it has an insignificant effect on OSS use directly. This calls for a study on the importance of community service quality in determining IS success. These findings highlight that both OSS use and user satisfaction have significant effects on individual net benefit.

From a practical perspective, the results offer suggestions to OSS practitioners on how to manage the development of OSS. First, OSS practitioners need to understand the five determinants of OSS success: software quality, community service quality, user satisfaction, OSS use, and individual net benefit. While many factors can be considered when assessing the level of OSS success, this study has proposed five determinants based on a literature review, which were empirically validated in the context of OSS usage.

Second, OSS practitioners need to understand the importance of software quality and community service quality among the five determinants of OSS success. Since these two factors have effects on the other success determinants both directly and indirectly, OSS practitioners need to put considerable effort into managing software quality and community service quality. To enhance software quality, OSS practitioners can attempt to manage various features of OSS including usefulness, ease of use, and reliability. In addition, providing a wizard for coding and appending the software may attract more users in contributing to the software.

To enhance community service quality, OSS practitioners can attempt to manage several aspects of service quality, such as reliability, responsiveness, assurance, and empathy. Technical support services come primarily from peer users or initiators of the OSS development community [2]. Users need support, cooperation, and assistance during both the development and post-development phases. Subsequent production of newer

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[3] Please refer to Dravis [4] for the high failure rate of OSS.

software versions after initial installation including upgrades, patches, and new releases may also be considered forms of support. Therefore, community service quality can be enhanced by the active participation of initiators of the OSS project, which would influence OSS user satisfaction. A poorly used OSS may not attract the enthusiasm of a new user. However, in an OSS where there are many contributors to the OSS project or the initiator is very contributive, new users may feel satisfied and desire to interact further.

Third, OSS practitioners can further attempt to manage the other three OSS success determinants: user satisfaction, OSS use, and individual net benefit. To enhance user satisfaction, as demonstrated by the results of this study, OSS practitioners need to make an effort to enhance software quality and community service quality. OSS use, however, is mainly influenced by software quality and user satisfaction. To enhance user satisfaction, OSS practitioners can attempt to analyze and understand user requirements first, and then reflect those requirements in the OSS project. Regarding individual net benefit, this study shows that it is influenced by user satisfaction and OSS use. To enhance OSS use, OSS practitioners can attempt to increase OSS community size. As the community size increases, there would be more users, and more users would facilitate feedback between users and OSS project managers and possibly result in increased OSS use.

7. Conclusion

The DeLone and McLean [12,15] IS success model is a widely accepted model for evaluating IS success [18]. However, empirical tests of this model in the OSS context are very few. This research constitutes one of the first empirical studies to measure OSS success by developing an OSS success model. Based on the existing models of IS success and a review of the relevant literature, we have developed an OSS success model with five determinants: software quality, community service quality, user satisfaction, OSS use, and individual net benefits.

Many previous studies have based their IS success model on the old DeLone and McLean [12] model, which does not consider the role of service quality. In this study we developed the OSS success model based on the updated DeLone and McLean [15] IS success model. Also, the existing empirical studies on IS success models [14,18,55] demonstrate that DeLone and McLean's [12] success model is quite context dependent. DeLone and McLean [56] assert the importance of understanding the context for applying the model

properly. Since there was no previous empirical study to measure OSS success, we applied the IS success model to the OSS context and found that the OSS success model shared similarities and differences with other contexts.

Our research presents important theoretical and practical contributions. On the theoretical side, this study developed and tested an OSS success model. Practically, this study provides guidelines for OSS practitioners on how to successfully manage OSS. Overall, this study contributes toward the theoretical advancement of OSS success and offers insights into improving the success rates for OSS projects. We hope this study will attract interest in further research on open source software success.

References

[1] Johnson JP. Economics of open source software. Working paper, Cornell University; 2001.

[2] Lakhani KR, Wolf RG. Why hackers do what they do: understanding motivation and effort in free/open source software project. Working paper, MIT Sloan School of Management/The Boston Consulting Group; 2003.

[3] Lerner J, Tirole J. Some simple economics of open source. The Journal of Industrial Economics 2002;50(2):197–234.

[4] Dravis P. Open source software: perspectives for development. World Bank Working Paper; November 2003.

[5] Chengular-Smith S, Sidorova A. Survival of open source projects: a population ecology perspective. In: The Proceedings of the twenty-fourth international conference on information systems; 2003.

[6] Mockus A, Fielding R, Herbsleb J. A case study of open source software development: the Apache server. Proceedings of the 22nd international conference on software engineering; 2000. p. 263–72.

[7] Moon JY, Sproull L. Essence of distributed work: the case of the Linux Kernel. First Monday 2000;5(11).

[8] O'Reilly T. Lessons from open-source software development. Communications of the ACM 1999;42(4):32–73.

[9] Stewart KJ, Gosain S. An exploratory study of ideology and trust in open source development groups. International conference on information systems; 2001.

[10] Stewart KJ, Ammeter TA. An exploratory study of factors affecting the popularity and vitality of open source projects. International conference on information systems; 2002.

[11] Crowston K, Annabi H, Howison J. Defining open source software project success. International conference on information systems, Seattle, WA; 2003.

[12] DeLone WH, McLean ER. Information systems success: the quest for the dependent variable. Information Systems Research 1992;3(1):60–95.

[13] Seddon PB. A respecification and extension of the DeLone and McLean model of IS success. Information Systems Research 1997;8(3):240–53.

[14] Livari J. An empirical test of the DeLone-McLean model of information system success. The DATA BASE for Advances in Information Systems 2005;36(3):8–27.

[15] DeLone WH, McLean ER. The DeLone and McLean model of information systems success: a ten-year update. Journal of Management Information Systems 2003;19(4):9–30.

[16] Byrd TA, Thrasher EH, Lang T, Davison NW. A process-oriented perspective of IS success: examining the impact of IS on operational cost. Omega—The International Journal of Management Science 2006;34(5):448–60.

[17] Seddon PB, Staples DS, Patnayakuni R, Bowtell M. Dimensions of IS success. Communications of the AIS 1999;2(20).

[18] Rai A, Lang SS, Welker RB. Assessing the validity of IS success models: an empirical test and theoretical analysis. Information Systems Research 2002;13(1):50–69.

[19] McKinney V, Yoon K, Zahedi FM. The measurement of web-customer satisfaction: an expectation and disconfirmation approach. Information Systems Research 2002;13(3):296–315.

[20] Crowston K, Scozzi B. Open source software projects as virtual organizations: competency rallying for software development. IEEE Proceedings Software 2002;149(1):3–17.

[21] Crowston K, Annabi H, Howison J, Masango C. Towards a portfolio of FLOSS project success measures. In: Collaboration, conflict and control: the 4th workshop on open source software engineering. International conference on software engineering (ICSE 2004), Edinburgh, Scotland; 2004.

[22] Igbaria M. End-user computing effectiveness: a structural equation model. OMEGA—The International Journal of Management Science 1990;18(6):637–52.

[23] Srinivasan A. Alternative measures of system effectiveness: associations and implications. MIS Quarterly 1985;9(3):243–53.

[24] Pitt LF, Watson RT, Kavan CB. Service quality: a measure of information systems effectiveness. MIS Quarterly 1995;19(2):173–87.

[25] Bhattacherjee A. Understanding information systems continuance: an expectation–confirmation model. MIS Quarterly 2001;25(3):351–70.

[26] Etezadi-Amoli J, Farhoomand AF. A structural model of end user computing satisfaction and user performance. Information & Management 1996;30(2):65–73.

[27] Goodhue DL, Thompson RL. Task-technology fit and individual performance. MIS Quarterly 1995;19(2):213–33.

[28] Seddon PB, Kiew MY. A partial test and development of DeLone and McLean's model of IS success. Australian Journal of Information Systems 1994; 90–109.

[29] Teo TSH, Wong PK. An empirical study of the performance impact of computerization in the retail industry. Omega—The International Journal of Management Science 1998;26(5):611–21.

[30] Wixom BH, Watson HJ. An empirical investigation of the factors affecting data warehousing success. MIS Quarterly 2001;25(1):17–41.

[31] Anderson E, Sullivan MW. The antecedents and consequences of customer satisfaction for firms. Marketing Science 1993;12(2):125–43.

[32] Bolton RN, Drew JH. A longitudinal analysis of the impact of service changes on customer attitudes. Journal of Marketing 1992;55(1):1–9.

[33] Oliver RL. A cognitive, affective and attribute bases of the satisfaction response. Journal of Consumer Research 1993;20(3):418–30.

[34] Bitner MJ, Booms BH, Tetreault MS. The service encounter: diagnosing favorable and unfavorable incidents. Journal of Marketing 1990;54(1):71–84.

[35] Lee HYL, Yoo D. The determinants of perceived service quality and its relationship with satisfaction. Journal of Services Marketing 2000;14(3):217–31.

[36] Bolton RN, Lemon KN. A dynamic model of customers' usage of services: usage as an antecedent and consequence of satisfaction. Journal of Marketing Research 1999;36(2):171–86.

[37] Davis FD, Bagozzi RP, Warshaw PR. User acceptance of computer technology: a comparison of two theoretical models. Management Science 1989;35(8):982–1003.

[38] Karahanna E, Straub DW, Chervany NL. Information technology adoption across time: a cross-sectional comparison of pre-adoption and post-adoption beliefs. MIS Quarterly 1999;23(2):183–213.

[39] Taylor S, Todd PA. Understanding information technology usage: a test of competing models. Information Systems Research 1985;6(2):144–76.

[40] Premkumar G, Bhattacherjee A. Explaining information technology usage: a test of competing models. Omega—The International Journal of Management Science 2008; 36(1):64–75.

[41] Schwarz N, Clore GL. How do I feel about it?: the informative function of affective states. In: Fielder K, Forgas J, editors. Affect, cognition and social behavior: new evidence and integrative attempts, 1988, Toronto, ON: C.J. Hogrefe; 1988. p. 44–62.

[42] Gatian AW. Is user satisfaction a valid measure of system effectiveness. Information & Management 1994;26(3):119–31.

[43] Livari J. Why are CASE tools not used? Communications of the ACM 1996;39(19):94–103.

[44] Leidner DE. Mexican executives' use of information systems: an empirical investigation of EIS use and impact. Journal of Global Information Technology Management 1998;1(2):19–36.

[45] Cheung W, Chang MK, Lau VS. Prediction of Internet and World Wide Web usage at work: a test of an extended Triandis model. Decision Support Systems 2000;30:83–100.

[46] Moore GC, Benbasat I. Development of an instrument to measure the perceptions of adopting an information technology innovation. Information Systems Research 1991;2(3):192–222.

[47] Pee LG. Behavioral factors affecting internet abuse in the workplace—an empirical investigation. Working Paper, National University of Singapore; 2004.

[48] Chin WW, Frye T. PLS Graph (Version 2.91.03.04). Calgary, Canada: University of Calgary; 1996.

[49] Anderson JC, Gerbing DW. Structural equation modeling in practice: a review and recommended two-step approach. Psychological Bulletin 1988;103(3):411–423.

[50] Hair JF, Anderson RE, Tatham RL, Black WC. Multivariate data analysis. fifth ed, Englewood Cliffs, NJ: Prentice-Hall; 1998.

[51] Fornell C, Larcker D. Evaluating structural equation models with unobservable variables and measurement error. Journal of Marketing Research 1981;18(1):39–50.

[52] Falk RF, Miller NB. A prime for soft modeling. Ohio: The University Press; 1992.

[53] Mason RO. Measuring information output: a communication systems approach. Information & Management 1978;1(5):219–34.

[54] Baron RM, Kenney DA. The moderator-mediator variable distinction in social psychological research: conceptual, strategic, and statistical considerations. Journal of Personality and Social Psychology 1986;51(6):1173–82.

[55] Gable GG, Sedera D, Chan T. Enterprise systems success: a measurement model. International conference on information systems, Seattle, WA; 2003.

[56] DeLone WH, McLean ER. Measuring e-Commerce success: applying the DeLone & McLean information systems success model. International Journal of Electronic Commerce 2004;9(1):31–47.

[57] Teo TSH, Yu Y. Online buying behavior: a transaction cost economics perspective. Omega—The International Journal of Management Science 2005;33(5):451–65.

[58] Teo TSH, Liu J. Consumer trust in e-commerce in the United States, Singapore and China. Omega—The International Journal of Management Science 2007;35(1):22–38.