Leadership characteristics and developers' motivation in open source software development

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A B S T R A C T

Open Source Software (OSS) is generally developed by interested professionals who have decided to participate in the process. The presence of effective leaders who both steer the development and motivate the developers is crucial to ensure a successful product. Using path-goal theory and built on leadership and motivation theories, we proposed and tested a model that can be used to assess the relationship between an OSS project leader's leadership style and a developer's motivation to contribute to the software development. We specifically decomposed the leadership and motivation construct to understand the hidden mechanisms by which leadership impacts motivation. A set of survey data collected from 118 OSS developers on Sourceforge.net was used to test our hypotheses. Our results indicate that leaders' transformational leadership is positively related to developers' intrinsic motivation and that leaders' active management style is positively related to the developers' extrinsic motivation.

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1. Introduction

Open Source Software (OSS) development differs from traditional proprietary software development because it is performed by a community rather than by paid employees [4]. Despite its voluntary basis, OSS has proliferated resulting in thousands of applications. For example, SourceForge.net, the world's largest OSS development web site, had successfully produced more than 324,000 software projects by the end of April 2012.[3] This suggests that OSS, though seemingly developed by a chaotic and anarchistic community, is becoming an important source of software.

One might wonder how an OSS project can attract substantial contributions from world-wide developers and yet be managed effectively [17]. In our view, the presence of leaders, who both steer the development direction and motivate the developers to contribute is crucial to ensure a successful outcome of an OSS project. For instance, the Apache project leader recognizes developers' effort by giving them rights to vote in determining the development direction of the project. Similarly, Linux and Perl projects have generated incentive structures to recognize developers' contributions.

In light of the importance of having authoritative figures, prior studies have postulated the importance of considering a good organization and coordination of activities in an OSS project, as well as the influence of motivation of an individual developer to contribute to an OSS project [15]. These factors correspond to the administration of the project and the participation of the co-workers (developers) respectively. However, no detailed study has previously been conducted to examine these factors together.

Given the fast development environment, practitioners are beginning to consider the possibility of incorporating OSS development strategies into the production of commercial software; this has been termed OSS 2.0, but unless knowledge is gained on the role of the OSS leader, the incorporation of OSS strategies into commercial software development will only be superficial.

We therefore sought to focus our research on understanding the effects of an OSS leader's leadership style on developers' motivation to contribute to a project. Using path-goal theory, we built on leadership and motivation theories to propose a model that posits the behavioral effects of OSS project leaders on developers' motivation to contribute. Contribution, here, was measured as the amount of time a developer spends on an OSS project. Our model was empirically assessed using survey data collected from 118 developers in an online OSS community. By

decomposing leadership into different styles and investigating their influence on the OSS developers' decision to contribute to the OSS project, we were able to gain a better understanding of the types of leadership approaches needed to succeed in developing an OSS project.

2. Theoretical background

Path-goal theory posits that leaders' behavior will affect their subordinates' motivation and in turn influence the outcome of a task; it was developed to explain how leaders motivate subordinates to achieve work-goal attainment by providing a facilitating work environment. Joshi et al. [6] investigated inspirational leadership in the context of virtual team management; and Pieterse et al. [12] compared the effect of transformational and transactional leadership on employees' innovativeness.

Studies on path-goal theory have mainly been conducted in a formal organizational structure, such as a company, but not in OSS projects where leaders often need to be careful in motivating their subordinates (OSS developers).

We therefore conducted a deeper investigation of the leadership process in a virtual organization by decomposing the leadership and motivation constructs. Consequently, we had to delve into two major building blocks of path-goal theory: the leadership theory and motivation theory (though self-determination theory).

2.1. Leader – Transformational and transactional leaderships

In our research context, an OSS leader is formed when he or she initiates an OSS project by creating software from the start, inherits the source codes from a former project leader who has since stopped working on it, or becomes a leader due to recognition and support from other developers. A leader, in the OSS community, possesses exclusive rights to decide on what features to include, when to release updated source code to the community, how to reward or punish contributors, and who to choose as a successor.

Studies on leadership have considered four aspects of a leader:

1. Power influence, which attempts to understand leadership in terms of the type and degree of power of the leader.
2. Behavior, which looks at the actual tasks the leader performs.
3. Trait, which considers the personal attributes of leaders, such as their energy, intuition, creativity, persuasiveness, charisma, and foresight.
4. Situational, which evaluates the leader's relationships with others (superiors, subordinates, and peers).

There are two polarized yet important leadership styles that depend on followers' behavioral response: transformational and transactional [2]. They differ in the way that a leader focuses on intellectual stimulation/inspiration or provide inducements to obtain desired performance by their subordinates.

A development of the transformational and transactional leadership paradigm lies in its application in the IS discipline, especially in the investigation of the R&D project team or virtual team task accomplishment and performance. It has been observed, for instance, in an R&D project team research, that transformational leadership was a strong predictor of technical quality of the project, and in virtual team studies [1] that transformational or transactional leadership styles could lead to different impact on the subordinates' behavior. To the extent that OSS project is a variation of the virtual R&D project team, we decided that this leadership style paradigm could be applied to the OSS project development context.

An individual possessing *transformational leadership* tries to induce desired follower behavior by intellectually stimulating or inspiring followers to ignore their self-interests for a collective purpose. It should affect followers in three ways: (1) increase their awareness of task importance and value, (2) change their focus to team goals rather than individual interest, and (3) activate their higher order needs. Transformational leadership dimensions include *idealized behavior* (charisma), *inspirational motivation* (stimulating optimism about the project), *intellectual stimulation* (promoting of new ways of thinking and solving problems) and *individualized consideration* (providing individualized care and consideration). While it can be effectively exerted through face-to-face interaction between leaders and followers, its effect may be reduced in virtual teams. However, recent leadership research [13] has shown that its effect on team performance was stronger in virtual teams than in face-to-face teams. We thus assumed that transformational leadership could still be exhibited online if the leader could motivate and promote the ways of thinking in which he or she believed.

In contrast, *transactional leadership* is characterized by a leader-follower relationship built on a series of bargains or exchanges. This occurs in two ways: structure and the execution. Through *structure*, a leader focuses on defining clear reward and punishment structures so that the followers know what is required. If both the leader and followers find the structure mutually rewarding, the relationship persists and the expected performance will occur. To execute transactional leadership, the leader can either engage on *active management by exception*, i.e., proactive supervision, or *passive management by exception*, i.e., reactive supervision. In the more active form of management by exception, the leader continuously monitors followers' performance; however, a leader who practices passive management by exception intervenes only after mistakes are made or standards are violated.

We contend that decomposing the leadership styles into subtypes will help us understand its impact on OSS project performance (by motivating developers).

2.2. Developers – Their motivations

According to self-determination theory (SDT), an individual's motivation in embarking on a task can be either intrinsic or extrinsic [3].

Intrinsic motivation is the drive to do an activity in order to experience pleasure and satisfaction, either enjoyment-based (the drive to obtain satisfaction through participating in an activity), or obligation-based (to meet the morals, values. and ethics dictated by an individual).

Extrinsic motivation involves a drive to take action to attain rewards, including career, prestige and positive evaluations from others or to avoid punishment. They are classified into three primary forms: identified regulation (e.g., an individual is motivated to perform an activity because it seems important and valuable), introjected regulation (when a person has pride in the results or feelings of guilt or shame), and the external regulation (when an individual performs an activity in order to receive external rewards or avoid punishment).

Intrinsic and extrinsic motivation concepts from the SDT theoretical lens have been applied extensively in the IS field. Hsu and Lin [5] studied motivation in acceptance of blog usage. In the field of OSS research, a group of researchers have classified OSS developers' motivation to contribute to the project into intrinsic (such as believing in the openness and freedom of software usage and distribution, pursing programming as a hobby, and enjoying working in the OSS community) and extrinsic (including improving programming skills, being recognized inside or outside the community, and needing better software than that provided through a proprietary channel).

While much has been learned about motivations of OSS developers, less attention has been paid to leadership as an antecedent to motivation and how different leadership styles influence motivation. We therefore proposed a model and verified it by performing a survey. Furthermore, as shown in Appendix A, both leadership constructs (transformational and transactional) and their motivation constructs (intrinsic and extrinsic) have been treated as a single construct although each of them has several different dimensions. Thus, by decomposing the leadership and motivation constructs and hypothesizing the relationships among them we sought to gain a deeper understanding of how leadership impacts motivation.

3. Research model and hypotheses

Anchoring on path-goal theory, the thesis of our research (see Fig. 1) was:

OSS leaders' different leadership style has differentiated, consequential impact on the motivations of the developers, this in turn affects developers' contribution to the project.

3.1. Transformational leadership and intrinsic motivation

Idealized behavior or charisma – the first dimension of transformational leadership – occurs when a leader becomes a role model of high ethical behavior and the developers react to this by wanting to emulate him or her [7]. An OSS leader demonstrates such behavior by communicating and articulating high values to the developers through email or a forum. Subsequently, developers are likely to adopt the same values and beliefs as the leader and become intrinsically motivated. This is *obligation-based intrinsic motivation*. OSS is a revolution in ideology [16]. Commonly held OSS beliefs include "outcomes are better when source code is freely available", "aiding others is important" and "voluntary cooperation is important." Thus we hypothesized:

H1a. OSS leader's idealized behavior is positively related to developers' obligation-based intrinsic motivation.

Inspirational motivation behavior – the second dimension of transformational leadership – occurs when a leader articulates a vision that is appealing and inspiring to followers; they challenge followers to adopt high standards, communicate optimism about their goals, etc. Such leaders articulate complex concepts simply. Such behavior can take place without a need for followers to identify with the leader. Such leadership works best with developers who have a strong sense of intrinsic purpose and meaning for working on the project. These obligation-motivated developers tend to feel encouraged and inspired if the OSS leader can articulate the vision and future of the project clearly and optimistically. The developers will thus be willing to invest more effort in their tasks. We hence hypothesized:

H1b. OSS leaders' inspirational motivation behavior is positively related to developers' obligation-based intrinsic motivation.

Intellectual stimulation behavior – the third dimension – occurs when a leader challenges the traditional assumptions and beliefs in order to seek new perspectives in solving problems. In doing so, the leader is setting up an environment that allows for self-determination and self-direction, by the followers. While enjoyment-based intrinsic motivation is a drive to perform an activity to experience the pleasure inherent to the activity, having the choice and opportunity for self-direction actually enhances this motivation as it affords a greater sense of autonomy and a feeling of challenge and stimulation. Similarly, we believe that being able to try something new will add to the enjoyment-based intrinsic motivation; for example, Linus Torvalds, always disseminates multiple problem definitions and solutions of the same issue to developers of Linux project in attempt to expose them to different ways of solving a problem. Hence, we posited that,

H1c. OSS leaders' intellectual stimulation is positively related to developers' enjoyment-based intrinsic motivation.
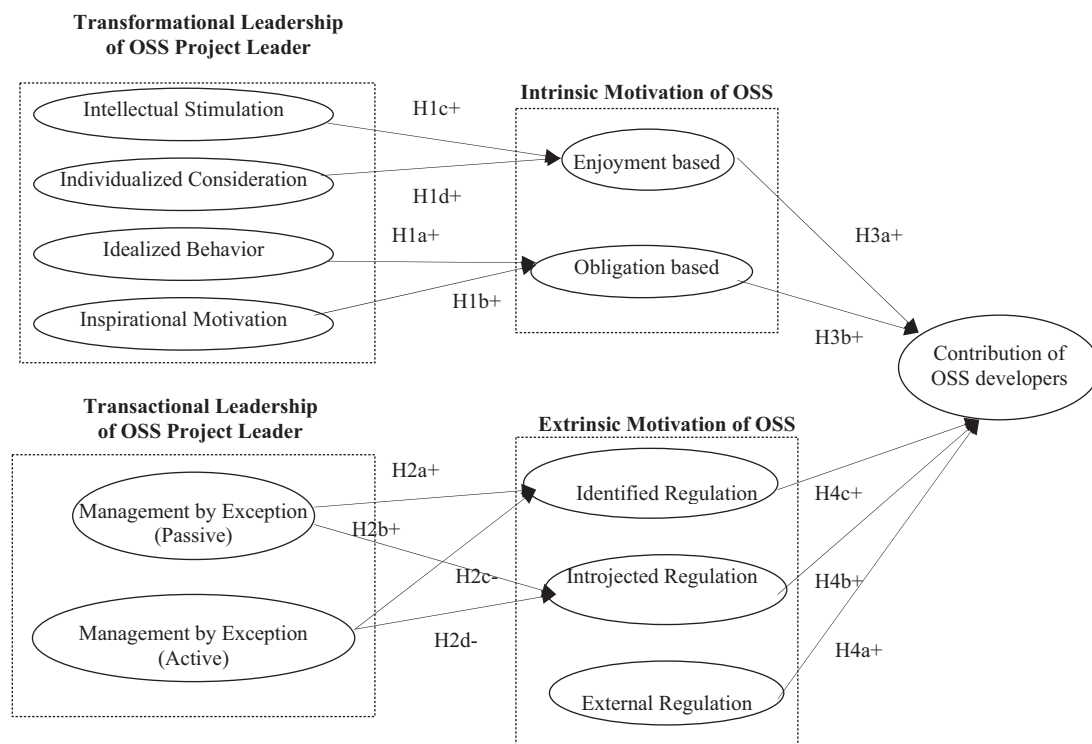

Fig. 1. Our research model.

When leaders provide individualized attention to developers in an attempt to understand and share their concerns and needs, *individualized consideration* occurs. By coaching and mentoring followers through email or forum communication, the OSS leader helps the developers to gain competence. Hence we hypothesized:

H1d. OSS leaders' individualized consideration is positively related to developers' enjoyment-based intrinsic motivation.

3.2. Transactional leadership and extrinsic motivation

Active management by exception, the first dimension of transactional leadership, occurs when leaders provide proactive supervision of the project's progress in order to ensure that no mistakes are made and that standards are met. Such leaders frequently scan for errors, make useful criticisms and feedback. While the effect of performance feedback on individuals' motivation has long been recognized, one of the tenets of OSS projects is frequent provision of feedback to contributors. Thus active management by exception could convince the developer that the activity is of personal importance, a form of extrinsic motivation. To exercise active management by exception, Linus offers constant and timely constructive comments to his Linux developers. Such responses help developers polish their programming skill and increase their marketability, which in turn makes them feel more motivated towards contribution. Hence, we hypothesized:

H2a. OSS leaders' active management by exception is positively related to developers' identified regulation type of extrinsic motivation.

Active management by exception can also positively affect introjected regulation, the second type of extrinsic motivation, which involves performing an action to improve self-esteem by receiving approval from ones-self or others. In the OSS community, being known as a hacker or a core member is equivalent to being given a badge of honor. In some OSS projects such as Apache, developers' continued high-quality contribution will be rewarded by project leaders with advancement in performance ranking, which in turn serves as an enhancement of self-esteem. For developers wishing to gain respect from peers and avoid any shame, timely feedback from a proactive OSS leader positively influences their introjected regulation motivation. Hence, we hypothesized:

H2b. OSS leaders' active management by exception is positively related to developers' introjected regulation type of extrinsic motivation.

On the other hand, *passive* management by exception – a reactive intervention by the leader only when things go wrong – could have a negative impact on both forms of extrinsic motivation. Such inactivity in scanning for potential problems could discourage developers who are keen to improve their skills, etc. We thus hypothesized:

H2c. OSS leaders' passive management by exception is negatively related to developers' identified regulation type of extrinsic motivation.

H2d. OSS leaders' passive management by exception is negatively related to developers' introjected regulation type of extrinsic motivation.

External regulation = the third form of extrinsic motivation - has an external locus of causality. It occurs when individuals are motivated by monetary rewards or punishments. Since the big

puzzle in OSS community is how OSS leaders can motivate developers, we shall not investigate how developers are motivated by monetary compensation, as this has been well studied in the traditional employment setting.

3.3. OSS developers' motivations and their contribution to the project

The ultimate task of leadership is to motivate the developers to perform to their best ability in contribution to the project. Thus the portfolio of behaviors that the OSS leader exhibits toward has a direct effect on the developers' motivation. In the context of OSS, great effort has been put into the investigation of determinants of developers' contribution to the project and the results have shown that developers contribute to OSS projects because they are intrinsically or extrinsically motivated. One recent OSS research effort [14] has shown that different motivations of OSS developers impact their participation in different ways. In spite of the importance of understanding how different motivations of OSS developers will affect their contribution to the project, it is not a focus of our study. Thus we generally hypothesized that motivation of developers, both intrinsic and extrinsic, would positively influence the developers' contribution to the OSS project.

H3a. OSS developers' enjoyment-based intrinsic motivation is positively related to their contribution.

H3b. OSS developers' obligation-based intrinsic motivation is positively related to their contribution.

H4a. OSS developers' external regulation is positively related to their contribution.

H4b. OSS developers' introjected regulation is positively related to their contribution.

H4c. OSS developers' identified regulation is positively related to their contribution.

4. Research methodology

We used a Survey to collect data from OSS developers; the dependent variable was measured by asking the OSS developers to report the estimated number of hours they spent on developing the OSS project weekly (coding for this measurement is shown in Appendix C). Although there are other measures of *contribution*, such as the number of submitted and accepted source code, the number of commit counts, and bugs fixed, because of the difficulty to assess all possible contributions (depending on the different roles of developers in the project), the time spent measure was the only common denominator. All the other variables were multi-item constructs measured using questions adapted from existing literature to ensure their validity. Leadership items were adapted from the MultiFactor Leadership Questionnaire[4] and motivation items were adapted from the Academic Motivational Scale (AMS)[5] (see Appendix B).

4.1. Conceptual validation

We tested our survey instrument by asking several OSS developers to identify and rectify potential problems due to the

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[4] B.M. Bass, B.J. Avolio, Full range of leadership development, Manual for the Multifactor Leadership Questionnaire. Mind Garden Inc., 1997.

[5] R.J. Vallerand, L.G. Pelletier, M.R. Blais, N.M. Briere, C. Senecal, E.F. Vallieres, The academic motivation scale: a measure of intrinsic, extrinsic and amotivation, Education. Educational and Psychological Measurement 52 (4) (1992) 1003–1017.

framing and wording of the questions. Next, we tested the instrument by conducting one unlabeled session and then one labeled sorting session with six judges in each session. We made some minor modifications based on the sorting results. The revised instrument was uploaded onto a website and three other OSS developers were asked to comment on the layout of the questions and highlight any that were confusing or difficult to answer. Subsequent revisions to the instrument were again verified by them before the survey was administered.

4.2. Survey administration

Online survey was administered to developers on SourceForge.net,[6] one of the largest OSS online communities, between April and May 2005. Sourceforge.net splits the status of the projects into six classes: "Planning", "Pre-Alpha", "Alpha", "Beta", "Production/Stable", "Mature" and "Inactive". For the administration of the survey, 1000 developers were randomly selected from OSS projects with the development status *Production/Stable* and having more than 10 members. The Production/Stable class was considered more successful in completing their tasks with all ready for use; they were also more active in development than *Mature* projects.

The online survey, consisting of a cover letter, survey instructions, and the survey instrument, was hosted on a web server; its URL was sent to the selected OSS developers with a password for access authentication. Since a developer may participate in several different OSS projects, each was asked to answer all the questions based on their participation and experiences in one particular OSS project on which they spent most time or effort. To increase the response rate, we provided a lucky-draw with attractive prizes. 187 responses were collected, a response rate of 18.7%, which we considered reasonable, as invitations were unsolicited. Only 118 responses were used in our data analysis, as the other 69 responses were found to be incomplete. Table 1 depicts the demographics of the respondents.

5. Data analyses

Partial least squares (PLS) was used for data analysis. It has many advantages over traditional statistical methods. First, it does not depend on having multivariate normal distributions, interval scales, or a large sample size, which suits our model. Second, PLS can simultaneously test the measurement model and the structural model. Third, it is generally more appropriate for testing theories in the early stages of development.

Hypotheses testing and all the statistical tests were conducted at the five-percent level of significance. Table 2 shows the descriptive statistics of the survey data.

5.1. Evaluating the measurement model

We subjected all multiple-item constructs to tests of convergent and discriminant validity. This involved calculation of the indicator loadings, Cronbach's alpha, composite reliability, and average variance extracted (see Table 3). All the multiple-item constructs demonstrated strong convergent validity. Individual item reliability was adequate if an item had a factor loading that was greater than 0.707 on its associated construct. The composite reliability and the Cronbach's alpha of all the constructs were well above the recommended score, indicating that there was adequate reliability. Every construct also had an AVE exceeding the normal criterion of 0.5, suggesting that the amount of variance in the items attributable to errors was less than the amount attributable to the construct.

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[6] www.sourceforge.net.

Table 1
Sample population demographics.

Demographics	Category	Frequency (N = 118)	Percentage (%)
Age	12–16	2	1.69
	17–25	35	29.7
	26–32	47	39.8
	33–40	19	16.1
	41–50	15	12.7
Primary occupation	Administrator	2	1.7
	Consultant	9	7.6
	Civil Engineer	1	0.8
	Educator/Trainer	5	4.2
	Electrical Engineer	2	17
	Government Civil Servant	1	0.8
	Network Administrator	2	1.7
	Professional	1	0.8
	Project Manager	3	2.5
	R & D Personnel	3	2.5
	Senior management	3	2.5
	Self-employed	4	3.4
	Student	24	20.3
	Software developer	35	29.7
	System Analyst	4	4.2
	System Administrator	7	5.9
	Unemployed/Between Jobs	5	3.4
	Others	5	4.2
Geographical location of residence	Africa	2	1.7
	Asia	7	5.9
	Europe	59	50.0
	Middle East	2	1.7
	North America	38	32.2
	Oceania	3	2.5
	Pacific Rim	2	1.7
	South America	5	4.2
Highest educational qualification obtained	High/Secondary School	21	17.8
	Junior College	7	5.9
	Polytechnic	1	0.8
	College/University	55	46.6
	Masters	29	24.6
	Doctorate	2	1.7
	Post doctorate	3	2.5
Education major	Business Administration	2	1.7
	Computer Science	55	46.6
	Engineering	17	14.4
	Economics	2	1.7
	Information Systems	6	5.1
	Law	1	0.8
	Language/Literature	2	1.7
	Life Science	1	0.8
	Mathematics	7	5.9
	Physics	6	5.1
	Philosophy	1	0.8
	Others	8	6.8
	None	10	8.5

Discriminant validity is the extent to which different items measure different constructs. We used PLS Graph Version 3.00 to assess the correlations between variables in any two constructs. Table 4 provides the results, which indicated that the square root of the variance shared between a construct and its indicators was greater than the construct itself and any other constructs, thus satisfying discriminant validity.

5.2. Testing the structural model

We used a bootstrapping procedure to estimate the significance of the path coefficients. Fig. 2 and Table 5 present the results of the analyses.

Table 2
Descriptive statistics.

Code	Constructs	No. of items	Mean	Std. deviation
TFLIS	Transformational leadership – Intellectual Stimulation	3	5.07	1.28
TFLIC	Transformational leadership – Individualized Consideration	4	6.01	1.09
TFLIB	Transformational leadership – Idealized Behavior	4	5.35	1.27
TFLIM	Transformational leadership – Inspirational Motivation	4	5.15	1.29
TSLMBEA	Transactional leadership – Management by Exception (Active)	4	4.23	1.44
TSLMBEP	Transactional leadership – Management by Exception (Passive)	3	3.19	1.43
EB-IM	Enjoyment based intrinsic motivation	4	5.87	1.10
OB-IM	Obligation based intrinsic motivation	4	5.36	1.44
ER-EM	External Regulation extrinsic motivation	4	4.63	1.69
INR-EM	Introjected Regulation extrinsic motivation	4	4.33	1.80
IR-EM	Identified Regulation extrinsic motivation	4	2.63	1.79
CTR	Contribution	1	4.37	1.73

Table 3
Convergent validity evaluation results.

Construct & item	Item reliability[***]	Composite reliability	Cronbach's Alpha	Average variance extracted (AVE)
Transformational leadership – Intellectual Stimulation		0.91	0.850	0.77
TFLIS1	0.89			
TFLIS2	0.91			
TFLIS3	0.83			
Transformational leadership – Individualized Consideration		0.90	0.856	0.70
TFLIC1	0.79			
TFLIC2	0.82			
TFLIC3	0.87			
TFLIC4	0.87			
Transformational leadership – Idealized Behavior		0.3	0.896	0.76
TFLIB1	0.85			
TFLIB2	0.92			
TFLIB3	0.84			
TFLIB4	0.88			
Transformational leadership – Inspirational Motivation		0.98	0.965	0.91
TFLIM1	0.94			
TFLIM2	0.95			
TFLIM3	0.96			
TFLIM4	0.95			
Transactional leadership – Management by Exception (Active)		0.90	0.858	0.70
TSLMBEA1	0.79			
TSLMBEA2	0.86			
TSLMBEA3	0.84			
TSLMBEA4	0.85			
Transactional leadership – Management by Exception (Passive)		0.85	0.790	0.66
TSLMBEP1	0.94			
TSLMBEP2	0.78			
TSLMBEP3	0.71			
Enjoyment based intrinsic motivation		0.94	0.910	0.79
EB-IM1	0.89			
EB-IM2	0.93			
EB-IM3	0.87			
EB-IM4	0.87			
Obligation based intrinsic motivation		0.89	0.839	0.68
OB-IM1	0.88			
OB-IM2	0.77			
OB-IM3	0.89			
OB-IM4	0.75			
External Regulation extrinsic motivation		0.91	0.877	0.73
ER-EM1	0.78			
ER-EM2	0.87			
ER-EM3	0.91			
ER-EM4	0.86			
Introjected Regulation extrinsic motivation		0.93	0.903	0.78
INR-EM1	0.93			
INR-EM2	0.73			
INR-EM3	0.95			
INR-EM4	0.91			

Table 3 (*Continued*)

| Construct & item	Item reliability[***]	Composite reliability	Cronbach's Alpha	Average variance extracted (AVE)
Identified Regulation extrinsic motivation		0.89	0.882	0.74
IR-EM1	0.90			
IR-EM2	0.83			
IR-EM3	0.91			
IR-EM4	0.79			

[***] All items are significant at $p < 0.001$ level.

Table 4
Discriminant validity of constructs.

Construct	TFL IB	TFL IS	TFL IC	TFL IM	TSL MBEA	TSL MBEP	EB IM	OB IM	IR EM	INR EM	ER EM	Contribution
TFL-IB	**0.88**											
TFL-IS	0.56**	**0.88**										
TFL-IC	0.59**	0.60**	**0.84**									
TFL-IM	0.55**	0.56**	0.55**	**0.95**								
TSL-MBEA	0.37	0.35	0.28	0.25	**0.84**							
TSL-MBEP	−0.10	−0.15	−0.19	−0.01	0.04	**0.81**						
EB-IM	0.32	0.40	0.40	0.29	0.24	−0.22	**0.89**					
OB-IM	0.41*	0.51	0.30	0.42**	0.34*	0.17	0.29	**0.82**				
IR-EM	0.16	0.23	0.09	0.12	0.35	0.01	0.31	0.30	**0.86**			
INR-EM	0.06	0.13	0.06	0.08	0.23	−0.10	0.19	0.12	0.61	**0.88**		
ER-EM	0.19	0.13	−0.04	0.10	0.21	0.08	0.01	0.08	0.31	0.16	**0.85**	
Contribution	0.25	0.18	0.07	0.28	0.24	−0.01	0.30	0.30	0.40*	0.24	0.35*	**1.00**

Note: * denotes significance at $p < 0.05$ level; **$p < 0.01$; ***$p < 0.001$. Diagonal elements are the square root of the AVE and all non-diagonal elements represent the correlations among constructs.
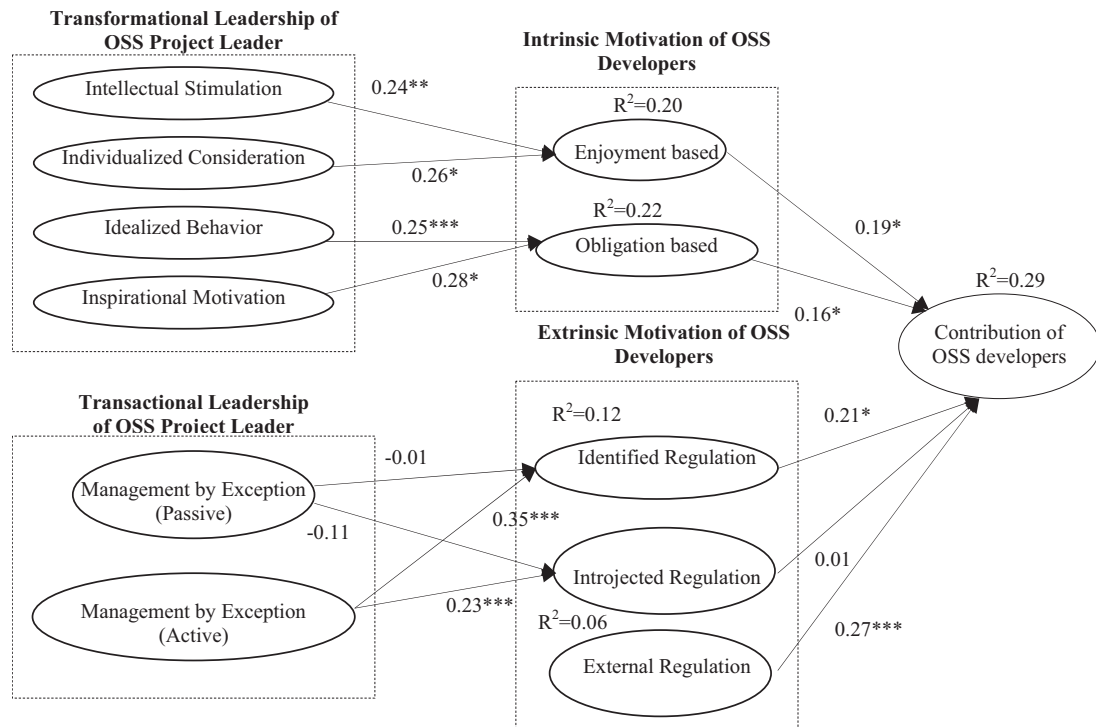
Note: * denotes significance at p<0.05 level; **p<0.01; ***p<0.001

Fig. 2. Results of hypothesis testing.

6. Discussions and implications

Our study concentrated on the relationship between leadership and OSS developers' motivation, and the relationship between it and their contributions to an OSS project. Our results indicated that OSS leaders' transformational leadership was positively related to OSS developers' intrinsic motivation and that OSS leaders' active

management by exception was positively related to OSS developers' extrinsic motivation.

Enjoyment-based intrinsic motivation is significantly affected by intellectual stimulation and individualized consideration. Idealized behavior and inspirational motivation can significantly influence obligation-based motivation. Relatively smaller proportion of variance is explained for identified regulation extrinsic

Table 5
Results of hypothesis testing.

Hypothesis (Path)	Path coefficient	t-Value	Supported
H1a: TransfIB→IntOM	0.25	3.40***	Yes
H1b: TransfIM→IntOM	0.28	2.31*	Yes
H1c: TransfIS→IntEM	0.24	2.52**	Yes
H1d: TransIC→IntOM	0.26	2.13*	Yes
H2a: TransAME→ExtIdR	0.35	4.30***	Yes
H2b: TransAME→ExtInR	0.23	2.81***	Yes
H2c: TransPME→ExtIdR	−0.01	0.04	No
H2d: TransPME→ExtInR	−0.11	0.73	No
H3a: IntEM→Contribution	0.19	1.85*	Yes
H3b: IntOM→Contribution	0.16	1.89*	Yes
H4a: ExtExR→Contribution	0.27	3.70***	Yes
H4b: ExtInR→Contribution	0.01	0.10	No
H4c: ExtIdR→Contribution	0.21	1.71*	Yes

Note: * denotes significance at $p < 0.05$ level; **$p < 0.01$; ***$p < 0.001$.

motivation and introjected regulation extrinsic motivation by active and passive management by exception. Furthermore, only active management by exception had a significant positive influence on these two types of extrinsic motivations, while passive management by exception was not significantly related to either.

Our results suggest that 29% of the variance of the dependent variable, contribution of OSS developers, can be explained by motivation variables. All these were significant except for introjected regulation.

6.1. Theoretical implications

In our research, we add to path-goal theory by explicitly considering the leadership styles, as manifestations of the leader's behavior. Furthermore, this theory has been conventionally developed and applied in a formal organizational structure, but has rarely been applied in any other structure. Thus our research tests the robustness of the theory.

Rather than conceptualizing a single relationship between leadership and outcome, we showed that different dimensions of each leadership style could have differentiated impact on different dimensions of each of the motivations. Furthermore, we found that passive management by exception was not significantly related to extrinsic motivations in our research context.

We tested two forms of leadership styles (transformational and transactional) in the OSS development context; these are seldom examined in an integrative fashion. Our study explored the influence of leadership on developers' motivation, from the perspective of the OSS developers. Since the evolution of the OSS community results in new governance models [9], our paper aids in the evolution of new management theory.

6.2. Practical implications

Effective leadership style is needed to motivate and attract contribution of OSS developers. By identifying different leadership behaviors that can catalyze or enhance the different forms of motivation, software companies keen can use them as guidelines for the leaders to motivate their developers.

Developers who are more likely to be intrinsically motivated (e.g., participate because of the fun and challenge of OSS) should be encouraged by leaders who exhibit transformational leadership, while developers who are extrinsically motivated (e.g., participate because of career incentives and programming skill improvement purposes), should have leaders who practice transactional leadership. In traditional commercial software projects, financial incentives are typically used to extrinsically motivate developers. However we found that in a community-based software project active management by exception by the leaders can be a substitute for financial incentive while passive management by exception is not significant in influencing developers' motivation.

6.3. Limitations

Caution must be exercised when interpreting our results. First, although the number of hours spent on the OSS project has been widely used to represent the contribution of OSS developers, this measurement may not be the best. Another measurement is the number of lines of codes contributed. However, this may not be easy to determine for each developer. Future work is not discussed in our paper.

Second, the relationship between OSS leader behavior and developers' motivation mat be affected by developers' factors such as their personality, demographic, and task characteristics.

Third, there is a possibility of common method bias in our study. We have collected our data on both independent and dependent measures through self-reporting at a single point in time. This might have caused respondents to respond with answers that they believed we hoped to receive. We minimized these effects by implementing the online survey questionnaire to prevent respondents from backtracking to change their answers, and we presented the pages of the survey in a random manner to discourage respondents from determining the relationship between the independent and dependent variables that we were trying to establish.

7. Conclusion

OSS is developed by a group of decentralized and geographically dispersed unpaid developers. To manage and motivate the developers, an OSS leader must possess a transformational nature, intrinsically motivating the developers, or a transactional nature to extrinsically motivate them. Anchoring on path-goal theory, our study has provided a holistic examination of the impact the leadership style on developers' motivation to contribute. We believe research on OSS leadership style deserves more attention, not only because of its theoretical implications, but also for its practical contributions towards making OSS project a success.

Appendix A. Recent research on leadership and motivation

Source	Method	Research focus	Results
[18]	Survey (Chinese Context)	The relationship between empowering leadership and employee creativity, with the mediating effect of psychological empowerment, intrinsic motivation and creative process engagement.	The empowering leadership positively affected psychological empowerment, which in turn influenced both intrinsic motivation and creative process engagement. These latter two variables then had a positive influence on creativity. These latter two variables then had a positive influence on creativity.
[11]	Survey (a very large scale one of over 6900 federal employees in US)	The influences of leadership and motivational variables, and especially public service motivation, on the "outcome" variables job satisfaction, perceived performance, quality of work, and turnover intentions.	Transformational-oriented leadership (TOL) fosters public service oriented motivation (PSOM) (interpreted as Intrinsic motivation) via empowerment in U.S. federal agencies. Both TOL and PSOM are positively related to job performance outcomes.

Appendix A (*Continued*)

Source	Method	Research focus	Results
[8]	Conceptual paper	To decipher how different leadership behaviors affect followers' motivation and performance by priming different modes of followers' self-regulatory foci (i.e., promotion or prevention). This paper has two focuses and only this one is closely relevant to our study.	Propositions that are closely related to our study (not tested): Charismatic and transformational leadership will prime followers' promotion motivational focus. Monitoring and transactional leadership will prime followers' prevention motivational focus.
[10]	Survey (cross-cultural)	Relationship between leadership style (participative, supportive and directive) and subordinates' motivation (a function of expectancies, instrumentalities, and valences), the moderating effect of national culture, and the subsequent impact on their performance, in the context of international marketing channel.	**USA data**: Participative leadership style is most strongly associated with motivation, followed by supportive and directive leadership style. **Finland data**: Participative, but not directive nor supportive, leadership style is significantly and positively associated with channel member motivation. **Poland data**: The three leadership styles – collectively – are unrelated to channel member motivation.

Appendix B. Operationalization of leadership and motivation constructs

Construct	Indicators	Scale
Transformational Leadership		
Idealized Behavior (TransfIB)	1. My OSS project leader articulates (through emails, forums, etc.) to us about his most important values and beliefs. 2. My OSS project leader specifies to us the importance of having a strong sense of purpose in OSS contribution. 3. My OSS project leader considers the moral and ethical consequences of OSS contribution. 4. My OSS project leader emphasizes to us the importance of having a collective sense of mission.	7-Point Likert Scale
Intellectual Stimulation (TransfIS)	1. My OSS project leader seeks differing perspectives/opinions from us when solving problems. 2. My OSS project leader gets us to look at problems from many different angles. 3. My OSS project leader suggests new ways of developing new functionalities for the OSS project.	
Inspirational Motivation (TransfIM)	1. My OSS project leader talks optimistically about the future of the project. 2. My OSS project leader articulates a compelling vision about the project. 3. My OSS project leader talks enthusiastically about what needs to be accomplished. 4. My OSS project leader expresses confidence that goals will be achieved.	
Individualized Consideration (TransfIC)	1. My OSS project leader spends time teaching and coaching. 2. My OSS project leader treats each developer as an individual rather than just as a member of a group. 3. My OSS project leader considers each developer as having different needs, abilities and aspirations from others. 4. My OSS project leader helps other OSS project developers to develop their strengths.	
Transactional Leadership		
Active Management-by-Exception (TransAME)	1. My OSS project leader focuses his attention on irregularities, mistakes, exceptions and deviations from standards. 2. My OSS project leader concentrates on dealing with mistakes, complaints and failures. 3. My OSS project leader scans for potential mistakes and keeps track of all mistakes. 4. My OSS project leader directs his attention towards failures in order to ensure that the OSS project developers meet his expectations.	
Passive Management-by-Exception (TransPME)	1. My OSS project leader fails to interfere until problems concerning the project become serious. 2. My OSS project leader waits for things within the project to go wrong before taking action. 3. My OSS project leader demonstrates that problems concerning the project must become chronic before he takes action.	
Extrinsic motivation		
Identified Regulation (ExtIdR)	I contribute to this OSS project because: 1. Contributing to the project will help me achieve my goal of making me more marketable. 2. It will help me achieve my goal of making a more informed career choice regarding the field of IT that I wish to pursue. 3. I believe that a few additional years of contributing to this OSS project will help me achieve my goal of improving my competence as a programmer. 4. Eventually, it will help me achieve my goal of increasing my marketability as a potential employee for firms.	7-Point Likert Scale
Introjected Regulation (ExtInR)	I contribute to this OSS project because: 1. I want to prove to myself that I can succeed in contributing to this project. 2. I want to prove to myself that I am a knowledgeable IT person. 3. I want to feel important when I succeed in contributing to this project. 4. I want to feel important when I receive recognition from the community.	
External Regulation (ExtExR)	I contribute to this OSS project because: 1. I receive some form of explicit compensation (e.g., income, contract) for contributing to this project. 2. In one way or another I will receive money from my participation in the project. 3. I will earn through consulting, training, implementation or customization services related to the project. 4. I am compensated to work for the project.	
Intrinsic Motivation		
Enjoyment-based Motivation (IntEM)	I contribute to this OSS project because: 1. Working with this OSS project development team is fun. 2. I enjoy working with this OSS project development team. 3. Writing this OSS project code is challenging. 4. Writing this OSS project code is enjoyable.	
Obligation-based Motivation (IntOM)	I contributed to this OSS project because, like other OSS developers: 1. I feel that source code should be open like OSS. 2. I feel a personal obligation to contribute since I am using OSS. 3. I feel that software should be available for free. 4. I identify with OSS community values.	

Appendix C. Coding of OSS developers' contribution

No. of hours per week	Percentile (%)	Coded no. of hours per week	No. of hours per week	Percentile (%)	Coded no. of hours per week	No. of hours per week	Percentile (%)	Coded no. of hours per week
100	100	7	10	59.8	5	4	24.7	2
60	99.1	7	10	59.8	5	4	24.7	2
40	96.5	7	10	59.8	5	4	24.7	2
40	96.5	7	10	59.8	5	4	24.7	2
40	96.5	7	10	59.8	5	4	24.7	2
32	95.7	7	10	59.8	5	4	24.7	2
30	94.0	7	10	59.8	5	4	24.7	2
30	94.0	7	10	59.8	5	4	24.7	2
27	93.1	7	8	52.9	4	4	24.7	2
26	92.3	7	8	52.9	4	3	16.2	2
25	90.5	7	8	52.9	4	3	16.2	2
25	90.5	7	8	52.9	4	3	16.2	2
24	89.7	7	8	52.9	4	3	16.2	2
20	77.7	6	8	52.9	4	3	16.2	2
20	77.7	6	8	52.9	4	3	16.2	2
20	77.7	6	8	52.9	4	3	16.2	2
20	77.7	6	6	50.4	4	3	16.2	2
20	77.7	6	6	50.4	3	3	16.2	2
20	77.7	6	5	35.8	3	2	4.2	1
20	77.7	6	5	35.8	3	2	4.2	1
20	77.7	6	5	35.8	3	2	4.2	1
20	77.7	6	5	35.8	3	2	4.2	1
20	77.7	6	5	35.8	3	2	4.2	1
20	77.7	6	5	35.8	3	2	4.2	1
16	76.0	6	5	35.8	3	2	4.2	1
16	76.0	6	5	35.8	3	2	4.2	1
15	72.6	6	5	35.8	3	2	4.2	1
15	72.6	6	5	35.8	3	2	4.2	1
15	72.6	6	5	35.8	3	2	4.2	1
15	72.6	6	5	35.8	3	2	4.2	1
14	70.0	5	5	35.8	3	1	0.00	1
14	70.0	5	5	35.8	2	1	0.00	1
14	70.0	5	5	35.8	2	1	0.00	1
12	68.3	5	4	24.7	2	1	0.00	1
12	68.3	5	4	24.7	2	1	0.00	1
10	59.8	5	4	24.7	2			
10	59.8	5	4	24.7	2			

Note: 1: 1–14%, 2: 15–28%, 3: 29–42%, 4: 45–56%, 5: 46–70%, 6: 71–84% and 7: >85%.

Appendix D. List of OSS projects responding to the survey

OSS project title	No. of developers	Activity percentile (%)	OSS project title	No. of developers	Activity percentile (%)
AMSN	31	99.9	Mailman	28	96.0
BZFlag – Multiplayer 3D Tank Game	55	99.7	MediaWiki	55	95.0
Clam AntiVirus	11	95.3	MonetDB – Monet Database Management Syst	27	91.0
Collective	222	99.1	Moodle	99	92.9
Columba	23	95.9	PCGen: An RPG Character Generator	64	99.6
Crystal Space 3D SDK	71	98.3	phpwsBB – phpWebSite Bulletin Board	12	95.9
DooM Legacy	39	96.4	Plone	88	95.1
FCKeditor	41	99.9	RainbowPortal	37	92.2
Fire	12	98.8	Scribus	8	95.6
Firebird	83	99.3	SquirrelMail	23	98.0
Gallery	27	99.6	SugarCRM	29	99.6
gPhoto	48	97.5	TortoiseCVS	29	99.4
Inkscape	33	99.6	UNICORE	26	89.4
IPCop Firewall	33	98.8	Vega Strike	49	93.4
JabRef	26	99.1	vpopmail – virtual domains for qmail	12	96.7
JBoss.org	122	99.3	WEBGui	27	95.2
JEDI VCL for Delphi	28	99.0	xine – a free video player	39	98.8
jEdit	112	98.8	XOOPS Dynamic Web CMS	76	99.8
LEAF – Linux Embedded Appliance Firewall	86	90.5			

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