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Research Article

Success Factors for Open-Source Software Development from Vendor's Perspective: An Empirical Study

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Abstract: Open-Source Software (OSS) development is an innovative paradigm to develop software by exploring unique solutions, acquiring the tacit programming knowledge of experts and to make the code freely available for reuse and improvement. OSS effectively delivers automation through a rich collaboration of geographically distributed experts with common goals and interests. OSS, being highly recognized in the software community is coined as futuristic model to meet ever the tremendous changes in requirements with high level of flexibility. Due to the increased positive economic impact, OSS is now globally adapted to deliver remarkable software with increased productivity. The principal aim of this research is to probe the state-of-art success factors in adapting OSS by conducting systematic literature review (SLR). To address the research questions, 159 studies were systematically analyzed, which resulted in 17 success factors. Out of the total list of identified success factors, four were pinpointed as significant, bearing high frequency. The significant success factors are "source code availability," "Low development cost," "High quality end product" and "Identification and fixing of bugs with ease". In addition, the results from SLR were validated through an online survey from relevant OSS experts globally. The findings of the questionnaire survey are mostly consistent with SLR results. The identified results provide insights to the software community in general and OSS developers in specific the propound success factors for adapting the OSS.

Keywords: Open-Source Software, Success Factor, Systematic Literature Review, Empirical Study.

1. INTRODUCTION

Open-Source Software (OSS) development is an innovative paradigm to develop software with exploring unique solutions, acquiring the tacit programming knowledge of experts and to make the code freely available for reuse, improvement, and further distribution [1]. OSS is an effective way to deliver automation through the rich collaboration of geographically distributed experts with common goals and interests. OSS, being highly recognized in software community is coined as a futuristic model to meet ever the tremendous changes in requirements with a high level of flexibility. Due to the increased positive economic impact, OSS is now globally adapted for the delivery of remarkable software with increased productivity, even Microsoft is now highly involved to deliver the OSS [2]. This tendency has reached to a high degree which is considered as a sustainable approach towards establishment of sustained economies through software development [3]. OSS acts as an essential part of the development of software. OSS has opened doors to new research paradigms in software development, and it has made the development process easy through the availability of source-code. OSS development offers tremendous benefits and has a wide range of acceptance in the global software business community. Some benefits include cost effectiveness, freely and easy access to source code, provides ease to accommodate rapid changes in requirements, effective distribution strategies, and a wide variety of source code according to platform and requirements. Hence, OSS is seen as the only possible and preferred solution for increased and in

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time software delivery from vendors' perspective, as well as from individual freelancer's perspective.

One of the critical success factors for which OSS got popularity is the availability of source code. Source code of such software is made available free for change and redistribution. Large pools of expert developers have access to source code, which reduces the costs and efforts of software development [2]. Everyone can download and use it according to the requirements. Due to the availability of source code, the developers can easily identify bugs and fix them, which improves overall software quality and ultimately speeds up the development process [3].

One of the major motivations for OSS is that volunteers or paid workers with diverse demography having deep knowledge, skills, and experience participate in OSS projects, and their knowledge is shared abundantly with OSS community [4]. OSS developers share their experiences, lightweight representations and refine requirements by writing comments to complete the projects. Some security aspects are also discussed by sharing attachments, external links, and snippets of the codes [5].

Hyung et al. [6] state that the structure of a project and developers' experience are the key indicators for OSS project success. Today, OSS has flourished in the software market, as the software industry has now realized the competitive advantages of OSS development and its tremendous adaption for increased and customized software productivity. OSS projects progressively tend to be integrated into large-scale projects or "software ecosystems" to minimize the software development efforts and boost innovative software productivity [7].

Beside the tremendous benefits of OSS for software development, it also poses some challenges, such as lack of proper documentation [8]. Developers from different demography and cultures are involved in development processes that do not provide any documentation as well as not able to provide support. There are also usability and design issues [9]. Though, there are some concerns regarding open-source software but for better decision making it is necessary in software development that the developers should have some knowledge of OSS adoption due to its tremendous benefits. Open-source software is preferred as a solution to numerous computing problems faced by software development organizations [10].

The principal objective of this paper is to identify the number of success factors in adapting OSS. In order to achieve our prime objective, the following questions have been devised:

RQ 1: What are the success factors, as identified in the literature, for adopting OSS?
RQ 2: What are the success factors, as identified in the real world practice, for adapting OSS?
RQ 3: Do the identified success factors vary across the two data sets, i.e. SLR and questionnaire survey?

The rest of the paper has been structured as follows: section 2 presents a background study of the OSS, section 3 describes the adapted research methodology to identify the success factors, section 4 discusses the results, while section 5 presents the conclusion and sheds light on the future work.

2. BACKGROUND OF STUDY

The practice of OSS development is an essential part of matured and well managed software industries. Affordability, reusability, adaptation, accessibility of the source code, low cost and the freedom of choice are the main features, which enabled open source (OS) as an ideal platform for several software companies and folks, who believed to practice the high strength code to produce remarkable software [11-13]. It has been observed that technological motivation for the development of OSS, clearly relates to the software crisis that traditional development does not reach efficiently like, speed, quality, and reduction in cost of development processes [11]. The main asset of OSS is its influence on external innovation, such as everyone is free to access, practice, assess, debug and enhance new competencies [12, 14]. OSS encourages the capability of the people to produce quality-oriented software with low cost and high quality across the globe [11, 15].

OSS offers numerous advantages, such as vendor independence, accessibility of complete source code with ease for possible bugs fixing and further customization, proprietorship to

plan feasible solutions with reduced cost prior to software deployment [16]. The practice of free and open-source software is gaining momentum worldwide with advancements in technologies and the trend of global software development through a large pool of experts [17]. Companies have also started adopting OSS, even though some reservations exist, particularly concerning the delivery and convenience of support [15]. One such great concern is the accessibility of support after a release and its management [17]. OSS development is considered as a practical approach for achieving high quality and standard software [18]. One such major aspect for achieving high quality in software is to identify a suitable association of fault density with other OSS metrics [19].

OSS is a gigantic repository of source code that is freely available to the software community with exceptional programming experience and expertise in knowledge formation through latest tools and frameworks [20]. To more strengthen the use of available source code, China has developed and made available OSS database OpenCom and is used by Shangai Library as a major component. OpenCom provides a user-friendly interface with interactive collaborative system to design, store and provide access with ease for developing OSS. To add, OpenCom provides rich extension for Reusable Asset Specification (RAS), to effectively support and collaborate the extensive source code to software developer's community [29-30].

Systematic literature review (SLR) has been used as a research methodology to point out the success factors in OSS from vendors' perspective. To the best of our knowledge to date, there is no SLR study published with reported success factors which present an effective role in developing OSS, which shows the novelty of this research work. Our results show that the vendor organizations have been informed about all potential success factors for adapting OSS platform for more secure and up to date software productivity. Appropriate awareness about the success factors in OSS development will also demand the findings of the approaches, solutions and tools, for addressing the risk factors confronted to OSS vendors, which is part of our future study.

3. RESEARCH DESIGN

SLR and questionnaire survey have been used as research methods, for identifying the potential success factors in the development of open-source software and then validating the findings from globally relevant expert community for its applicability. These approaches were used because of the nature and the type of research and data used, and it also depends on the required analysis to address the prime objectives of the research. Our research design strongly supports the nature of our research to meet the desired results, as adapted by other empiricists [21-26].

3.1. Systematic Literature Review (SLR)

Systematic Literature Review (SLR) has been used as a research method because it is thorough, unbiased, ultra-careful, and produces reliable results as compared to ordinary literature review. Systematic reviews probe authentic research articles to be evaluated according to the designed research string and research questions. The results of SLR are comparatively more concise and valid as compared to ordinary literature reviews [21-28]. The following sub sections describe certain steps for SLR methodology carried out during the conduction of this research.

3.1.1. Problem Identification

The main objective of our research is to identify the success factors in OSS from vendor's perspective. Research questions have been designed to meet the problem, as presented in introduction section.

3.1.2. Data Sources

In this phase, we used a trial search string, using multiple digital libraries. It was purely based on the access offered. To accomplish the search phase of our SLR the digital libraries IEEE Explore (www.ieeexplore.ieee.org), Science Direct (www.sciencedirect.com), ACM Digital Library (www.dl.acm.org), Wiley Online Library (www.onlinelibrary.wiley.com) and Springer Link (www.link.springer.com) were searched. Table 1 presents a list of final searched sources, searched terms, and for each resource the entire number of articles found. We chose these databases because of the

previous SLRs experiences and after discussing them with our fellows at the University.

("Motivators" OR "Success Factors" OR" Benefits" OR "Advantages") AND ("Open-source software" OR "Free source-code" OR "OSS")
Table 1 shows the finally selected list of resources that have been searched during this phase. We found a different number of papers in the respective digital library. A similar methodology was also adopted by researchers [30-33].

3.1.3. Selection of Publications

Criteria for Inclusion:
To select the relevant publications the following inclusion criteria has been used:

- Papers that are related to the field of Computer Science research background and written in English language only.
- Research studies which narrate the concept and success factors/benefits/ of OSS
- Research studies which clearly present the approaches/patterns for developing OSS
- Research studies which present and justify the need of adapted tools and technologies for the development of OSS

Criteria for Exclusion:

To exclude the irrelevant studies and keep a list of relevant papers more concise, we adapted the following criteria:

- Research studies that do not meet the inclusion criteria
- Research studies, other than in the English language

3.1.4. Publication Quality Assessment

After the final selection of the papers, we assessed the quality by designing the below mentioned questions as a standard checklist. It is mandatory to apply the quality criteria to obtain only the relevant and high-quality papers for better results. The following questions are used as a standard checklist:

A. Is there a clear description of adapting OSS development? (Yes/No/Partially) Is there a clear presentation of the methodology used to identify success factors/benefits for OSS?
B. Is it clear that in which way the success factors in Open Source Software were identified? (Yes/ No/Partially)
C. Do the results reflect the research questions in an understandable way?

To validate the quality of final selected papers, some papers were randomly selected by the secondary reviewer and checked it against the designed quality checklist. Few papers were excluded, as

Table 1. Data sources and search string results

S. No	Digital Library	Search String	Search Date	Covered Years by Search	Total Publications Found	Primary Selection	Final Selection
1	IEEE XPLORE	*("Motivators" OR "Success Factors" OR "Advantages" OR "Benefits) AND ("Open-source software" OR "free source code" OR "OSS")*	Jan 2018 To Dec, 2019	All	2,095	293	41
2	Science Direct				222	110	37
3	ACM				228	73	23
4	Springer Link				1,564	244	41
5	Wiley Online Library				180	113	17
				Total	4289	833	159

those did not fulfill the quality measures. Only those papers were included which meet the research questions and quality criteria and all other papers were excluded.

Initially, in this phase of searching, 42891 papers were searched, as presented in Table 1. Then via title reviewing and abstract of every paper in the searching phase, we chose 833 papers as primary selected papers. Then after using the previously mentioned inclusion and exclusion criteria, we chose 159 papers for our final selection. Thus, for data extraction phase we were left with 159 papers as our final sample, as shown in Table 1.

3.1.5. Data Extraction and Synthesis

In the data extraction phase, we extracted data through a pre-defined form from each final selected paper. The data extraction form contained the values: Review date, Title of Paper, Authors, Year, Database, success factors that have an optimistic influence on OSS, Research Methodology, Targeted Population, Type of Organization, Size of Company and Country.

Our final list contained 159 papers. After carrying out data extraction, data synthesis was performed to finalize and synthesize the success factors from the data in data extraction phase.

The principal reviewer in consultation with the secondary reviewer, synthesized the obtained data. In the wake of a detailed review with external reviewers, from a total of 159 research papers in OSS, we identified 17 success factors, as shown in Table 2.

After identification of success factors/ motivators for OSS from vendor's perspectives, we categorized some success factors as discussed and shown in the results section.

A particular factor was termed as significant if its frequency is greater than 35%. Out of the total list, significant success factors are "source code availability", "Low development cost", "High quality end product" and "Provides Identification and fixing of Bugs with ease".

3.2. Empirical Validation through Questionnaire Survey

To validate the results of the SLR, we conducted online questionnaire survey in OSS industry. We conducted the survey for two purposes, first to validate our SLR findings through relevant OOS experts from software industry in and then to find any new factor besides the identified list of success factors. Therefore, we adapted questionnaire as a tool to gather the self-reported data (available at https://bit.ly/2RIqabb). We added below statement to achieve the purpose of conducting the survey, to validate the SLR findings:

"Through survey we are confirming whether or not the stated outcomes apply exactly, or can be applied, in OSS".

We used Google forms, the free online tool for the development of a questionnaire, which is easily available. The questionnaire also includes some open-ended questions to probe some new success factors from participants' side, if any, to comprehend our list of success factors. A similar method has been used by other researchers [21-28].

The participants of the questionnaire were requested to provide feedback on a 7-point Likert scale. Apart from these, we also added some open-ended questions, where the participants were free to append the list of success factors, if any.

To reach the relevant target pool of experts, we joined several online professional forums/ groups on LinkedIn. We also joined several open-source software related online research groups to access OSS experts to invite the relevant experts for participation in our research survey. We also contacted the practitioners and authors of papers by sending emails to them individually. The participants' list was quite diversified, in which experts from different zones participated

4. RESULTS

4.1. Systematic Literature Review

To answer RQ1, Table 2 enlists a total of 17 success factors in OSS from vendor's perspective. We have categorized four success factors as significant

success factors, as portrayed in Table 2, according to their high frequency percentage. The factors are sorted on their frequency percentage and some of these have been termed as significant; the factors having frequency percentage > 35 is called significant, according to our research criteria. The significant success factors are "source code availability – 57%", "Low development cost – 47%", "High quality end product – 40%" and "identification of bugs it's fixing – 38%".

4.2. Questionnaire Survey Findings (RQ2)

To answer RQ2, we conducted a questionnaire survey using Google forms, discussed in Section 3. It aimed to validate the results, i.e., the success factors from OSS industry experts and to probe some new factors, if any from experts' side, to comprehend the list of success factors. The sole purpose of conducting the survey was to obtain the experts' perception about the findings through 7 points Likert scale. In this survey, 72 OSS experts from several countries participated.

Close ended questions were used in questionnaire' survey with an additional option for identification of unseen success factors. The participants were requested to answer on a 7-point Likert scale. Apart from these, we added some open-ended questions, where the participants have been requested to add more success factors besides the identified ones.

Results of the questionnaire survey, as illustrated in Table 3. validates the findings of SLR as a positive response is greater than 50%. We have only considered the positive response for the validation of our results. The optimistic result of the questionnaire survey, as presented in Table 3. demonstrates that the identified list of success factors is significant for OSS vendors. Figure 1 and Figure 2 present the details of survey participants, i.e., experience and their company demographics.

Table 2. List of success factors in OSS identified through SLR

S. No.	Success factors	Total Papers: 159	
		Frequency	%
1	Source Code Availability	91	57
2	Low development cost	74	47
3	High quality end-product	63	40
4	Provides Identification and fixing of Bugs with ease	60	38
6	Increased innovation	37	23
7	Code reusability	35	22
8	Increased software Productivity	47	30
9	Secure end-product	34	21
10	Diversified External support	33	21
11	Reduced vendor lock-in	14	09
12	Provides extrinsic rewards	13	08
13	Intrinsic rewards for non-monetary developers	12	08
14	Boosts country's Economic Growth	10	06
15	Extensive knowledge sharing through globalized teamwork	08	05
16	Self-organized system	07	04
17	Source code Peer-review	06	04

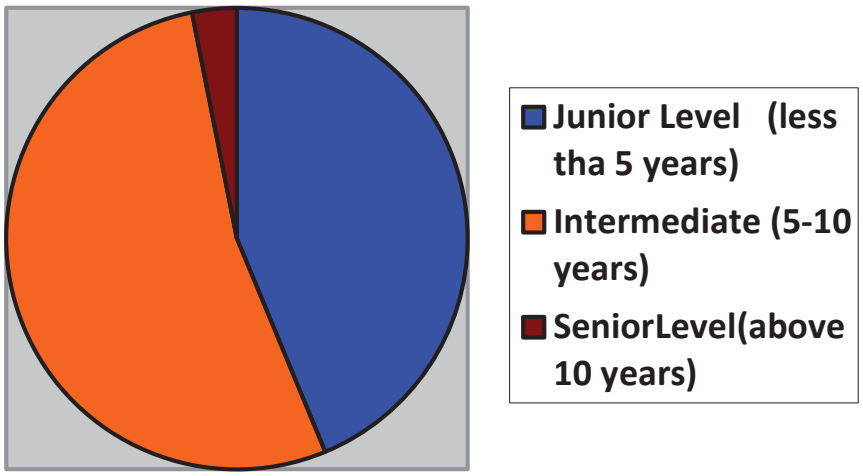

Fig. 1. Details of survey participants' experience

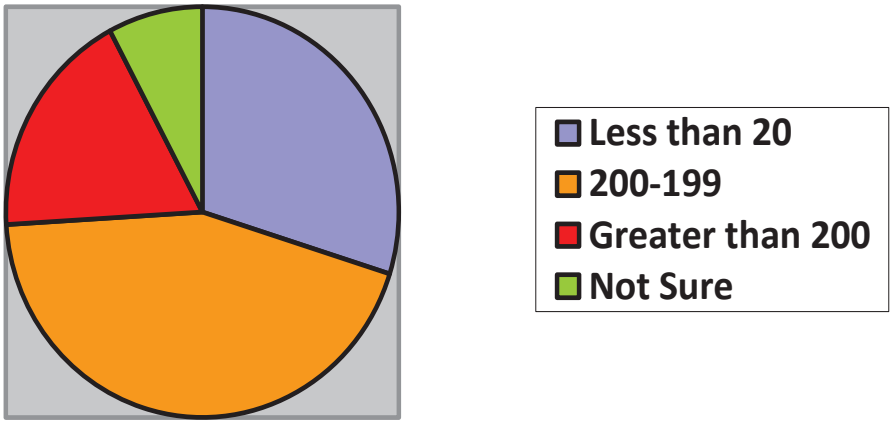

Fig. 2. Details of participants' company size

4.3 Comparative Analysis of The SFs Across The Two Different Data Sets (SLR vs Questionnaire Survey) (RQ3)

In order to investigate the resemblance and conflicts among the identified success factors, through SLR and questioners survey, we cross compared the data from both data sets, as shown in Table 4.

It should be noted that in Table 4 the success factors having the highest values have been indicated with the lowest ranks and so on. Success factors with the same values have been assigned equal average rank. Similarly, the next success factor is adjusted with next value appropriately. For instance, in Table 4. both "Secure end product" and "Diversified External support" have the same value i.e., 21, so they are assigned the average rank of value 9 and 10 i.e., 9.5 while "Reduced vendor lock-in" having the next highest value is assigned rank 11, as the ranks 9 and 10 are already used.

In order to explore some more unobserved success factors and to enrich the identified list, we have included some open-ended questions, which gave freedom to the participants for inclusion of more factors, they have experienced. However, no more factors were added by the questionnaire participants and all were agreed and satisfied with the identified list; hence both the data sets remain the same with no noticeable change, as shown in Table 4.

Empirical results in Table 3 demonstrate that no single success factor shows zero frequency. It should be noted that the ranks of both data sets are

Table 3. Detailed scores for each success factor in Questionnaire

Success Factors OSS Development	**Strongly Agree**	**Moderately Agree**	**Slightly Agree**	**Not Sure**	**Strongly Disagree**	**Moderately**	**Slightly Disagree**
Source code availability	33	18	5	11	2	2	1
Low development cost	31	17	14	7	2	1	0
High quality end-product	31	20	9	9	2	1	0
Provides Identification and fixing of Bugs with ease	31	20	9	5	5	1	1
Code modifiability	40	18	12	2	0	0	0
Increased innovation	32	20	11	6	3	0	0
Code reusability	39	23	8	2	0	0	0
Increased software Productivity	34	20	8	5	4	1	0
Secure end-product	33	14	8	14	1	0	2
Diversified External support	26	26	11	3	4	1	0
Reduced vendor lock-in	27	15	15	8	3	3	1
Provides extrinsic rewards	26	16	10	10	5	4	1
Intrinsic rewards for non-monetary developers	27	26	10	7	1	1	0
Boosts country's Economic Growth	37	26	3	4	1	1	0
Extensive knowledge sharing through globalized teamwork	30	23	9	7	2	1	0
Self-organized system	31	18	14	5	2	1	1
Source code Peer-review	34	20	9	6	1	2	0

Table 4. Comparison of the two data sets, for OSS

Success Factors OSS Development	**Occurrence in SLR (*N=159*)**		**Extremely Agree % in the Questionnaire Survey (*N=72*)**		**Average Rank**
	%	Rank	%	Rank	
Source code availability	57	1	43	7	4
Low development cost	47	2	42	9.5	5.75
High quality end-product	40	3	40	12.5	7.75
Provides Identification and fixing of Bugs with ease	38	4	44	4.5	4.25
Code modifiability	35	5	54	1	3
Increased innovation	23	7	42	9.5	8.25
Code reusability	22	8	53	2	5
Increased software Productivity	30	6	43	7	6.5
Secure end-product	21	9.5	43	7	8.25
Diversified External support	21	9.5	36	14.5	12
Reduced vendor lock-in	09	11	36	14.5	12.75
Provides extrinsic rewards	08	12.5	35	16.5	14.5
Intrinsic rewards for non-monetary developers	08	12.5	35	16.5	14.5
Boosts country's Economic Growth	06	14	50	3	10.5
Extensive knowledge sharing through globalized teamwork	05	15	40	12.5	13.75
Self-organized system	04	16.5	41	11	13.75
Source code Peer-review	04	16.5	44	4.5	10.75

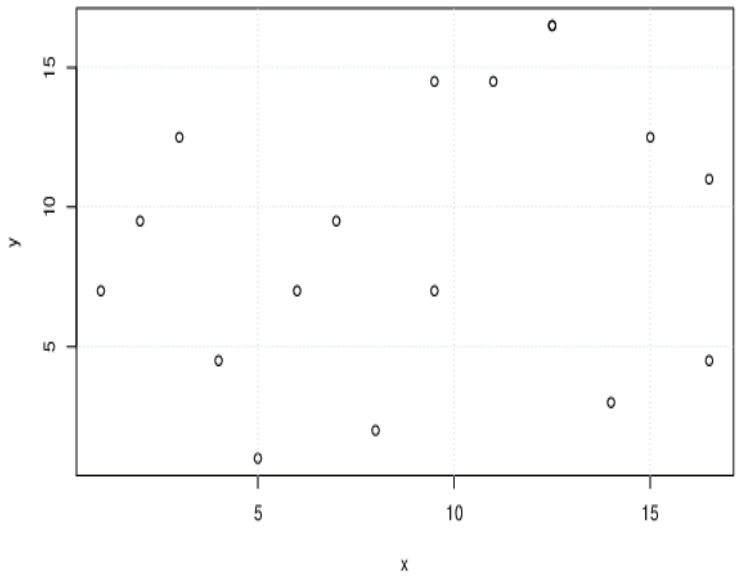

Fig. 3. Correlation scatter plot for Success Factor through SLR and Questionnaire

quite dissimilar, e.g., "Source code availability" is rank number 1 in SLR data, while it has got rank 7 in the questionnaire, as shown in Table 4.

To examine the variances among the identified success factors through questionnaire survey and SLR, we conducted Spearman's rank-order correlation, as portrayed in Table 4. It is significant to observe that these success factors have no similar ranking in both data sets. The value of Spearman's correlation coefficient i.e., 0.235 reflects a strong correlation in ranks of both the data sets, where the p-value 0.362 implies that we have no significant dissimilarity between the industrial survey results and the SLR. In Fig 3, scatter plot reveals that both data sets have more likenesses than dissimilarities.

5. CONCLUSION AND FUTURE WORK

Open-Source Software development is an innovative paradigm to develop software with exploring unique solution, to acquire the tacit programming knowledge of experts and to make the code freely available for reuse and improvement. OSS is an effective way to deliver automation through rich collaboration of geographically distributed experts with common goals and interest. OSS being highly recognized in software community is coined as futuristic model to meet ever the tremendous changes in requirements with high level of flexibility. Due to high positive economic impact, OSS is now globally adapted for delivery of remarkable software with increased productivity. The principal aim of this research is to probe the state-of-art success factors in adapting OSS by conducting systematic literature review (SLR). To address the research questions, 159 studies were systematically analysed which resulted 17 success factors. Out of the total list of identified success factors, 4 were pinpointed as significant, bearing high frequency. The results of this research give insight to OSS vendors to focus on and address the identified success factors to meet the desired results with remarkable open-source software delivery. Further, the identified success factors, if considered, would have a positive impact on the overall development process with increased and reliable software productivity and distribution of freely available source code.

Based on the findings of this research, we have planned the following research objectives, to be carried out in the near future, to more strengthen the existing research work, and to stress the OSS vendors' community to meet the maximum benefits of OSS paradigm.

- To identify the practices for addressing the identified success factors
- To identify the potential risk factors in adapting open-source software development from

vendors' perspective
- To identify the practices for addressing the identified success factors and risk factors
- To develop open-source software development maturity model (OSSDMM) to measure the maturity level of vendor organization in implementing open-source development strategy
- To conduct multiple case studies at software vendor organizations to evaluate the efficacy of the model

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