Requirements Engineering in Open Innovation: A Research Agenda

Johan Linåker  
Lund University, Sweden  
Johan.Linaker@cs.lth.se

Björn Regnell  
Lund University, Sweden  
Bjorn.Regnell@cs.lth.se

Hussan Munir  
Lund University, Sweden  
Hussan.Munir@cs.lth.se

ABSTRACT

In recent years Open Innovation (OI) has gained much attention and made firms aware that they need to consider the open environment surrounding them. To facilitate this shift Requirements Engineering (RE) needs to be adapted in order to manage the increase and complexity of new requirements sources as well as networks of stakeholders. In response we build on and advance an earlier proposed software engineering framework for fostering OI, focusing on stakeholder management, when to open up, and prioritization and release planning. Literature in open source RE is contrasted against recent findings of OI in software engineering to establish a current view of the area. Based on the synthesized findings we propose a research agenda within the areas under focus, along with a framing-model to help researchers frame and break down their research questions to consider the different angles implied by the OI model.

Categories and Subject Descriptors

D.2.1 [Software Engineering]: Requirements

Keywords

Software engineering, Requirements engineering, Open innovation, Open source, Stakeholder management, Prioritization, Release planning

1. INTRODUCTION

Due to the eruption of new ways in communicating and working distributed, along with e.g. lowered barriers for startups and increased access to knowledge sources, software producing firms now need to explore and exploit their outside surroundings to a higher degree than before to complement their internal innovation capabilities [1]. This phenomenon is captured by the paradigm of Open Innovation (OI), defined by Chesbrough [1] as “a paradigm that assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as they look to advance their technology”. The OI model incorporates multiple applications. In Software Engineering (SE) the most common example probably is Open Source Software (OSS) [16], which has been around for decades and proven to be a useful and important building block in product strategies among software producing firms. The emergence of the OI paradigm has highlighted this fact even more in the sense that OSS may be used to better leverage and advance firms’ internal technical and innovation capital [24]. Requirements Engineering (RE), which is pivotal for a software development project to succeed, needs to take the changes implied by OI in regard and adapt accordingly, e.g. to consider how firms should reach out, explore and manage the new potential stakeholders, users and customers, for which requirements can be elicited from or outsourced to.

In this paper we build on and advance the proposed SE framework for fostering OI by Wnuk and Runeson [26]. We also propose a research agenda with several research questions regarding RE practices in relation to OI and how these could or should be adapted in order to enable for and optimize the outcome for firms using an OI strategy. The proposed research agenda suggests a number of research directions in different sub-disciplines of RE. The research questions elaborated on in this paper are in line with the proposal by Wnuk et al. [26] to “...focus on release-planning, stakeholder analysis, trade-off between effort (cost) and value and the degree of innovation in candidate features needed in evolving systems, to take significant future market shares in open innovation software development”, and our main conjecture is that these trade-offs constitute essential and hard problems of future software RE, and these problems are further complicated in an OI context.

In section two, the methodology is presented in short. In section three, synthesized results from OSS RE and OI literature are presented. In section four a model is presented to help frame RE in an OSS and OI setting along with suggestions for future research. The paper is concluded in section five.

2. METHODOLOGY

Based on the research direction within RE in OI suggested by Wnuk et al. [26], we conducted a literature survey of RE practices in OSS within the areas of stakeholder identification and management, contribution strategies and opening up criteria, and prioritization and release planning. These results were compared and contrasted against recent findings of OI in SE reported by Munir et al. [16]. Findings where synthesized in the categories ...
3. CONTRASTING LITERATURE

On the basis of our literature survey, we elaborate and contrast between RE in OI and OSS in regards to the areas of Stakeholder management, When to open up a firms software, and Prioritization and Release planning.

3.1 Stakeholder Management

We refer to the definition of Glinz and Wieringa [7] and define a stakeholder as “...a person or organization who influences a system’s requirements or who is impacted by that system”, with system meaning an OSS project. With stakeholder management we consider both identification of the stakeholders and analysis of their interest or intent in an OSS project and its community. This is a problematic area due to that the open environment implied by OI allows for an influx of new and earlier unknown stakeholders into a firm’s formerly closed domain. Staying aware of who else are present in a community and what their intents are may therefore prove difficult. Ignorance may constitute a risk and jeopardize a firm’s stake in the OSS. Also, with an awareness, opportunities could arise as stakeholders with aligning intents and complementary competences may be found. Another issue besides awareness, is managing conflicts and different needs of the stakeholders [16]. As they may have clashing intents with business stakes involved, creating a common vision becomes troublesome [2]. In such cases it may be beneficial to know who are aligned and those to persuade, as some stakeholders could be unknown and reside silent until confronted.

Stakeholder management may hence be considered an important area to master for a firm to adapt itself to an OSS community, as well as to gain and maintain a profitable position with sustainable influence in the community’s governance structure [2]. Consequently, it may further be considered an enabling factor for firms to more effectively be able to perform other RE practices such as elicitation, prioritization and release planning in relation to the community [7].

In an OSS community stakeholders may be identified by the natural means they communicate, both electronically (e.g. mailing lists, forums, IRC) and in-person (e.g. conferences, hackathons). For the former type, a multitude of quantitative analytical methods exists to identify present stakeholders (e.g. [13, 12]). Tools also exist, which allow for further analysis to be performed on the earlier mentioned software repositories, but also on other types, e.g. source code repositories and issue trackers [19]. However, quantitative analysis can only bring you to a certain point. To get a clearer view, a qualitative analysis could be performed as well, either by observing, engaging or a combination of them both. Regards should be taken to both the electronic and in-person communication channels. As social events and live meetings are becoming increasingly popular, firms may need to consider distributing their presence offline as well [21]. Some stakeholders may not be as vocal online as they are offline, why these could risk going unnoticed. Furthermore, by showing one self and giving notice on one’s intents and knowledge, this may attract some stakeholders to come out of the shadows.

Different kinds of stakeholders may be found in different communication channels, Knauss et al. [11] describe how requirements are communicated between stakeholders in two different flows in an open-commercial software ecosystem, which also transfers to an OSS community. First, an emergent requirements flow captures requirements as developers and users find new ways of using the software and present these on a work-item level, much as how e.g. prototypes and other informalisms are used as post-hoc assertions in OSS RE [20]. Second, a strategic flow is used to communicate the business goals and strategies of the different stakeholders.

For analyzing the stakeholders’ intents similar methodologies may be applied as for identification. Regarding quantitative methods, Gonzalez-Barahona et al. [8] describes how patterns may be found in how other stakeholders contribute (e.g. feature implementations, bug-fixes, discussions), how the projects generals stance is on certain topics, and how stakeholders work together (e.g. on implementation, decision-making). This information may then be used to analyze their intents and strategies (e.g. what functionality they value most, in what direction they are striving towards, how committed they are), and to find potential collaboration opportunities. Modeling the relationships between the stakeholders may be a further step to help create a better picture. Fricker [6] suggests how relations amongst stakeholders in software ecosystems may be modeled as requirements value chains, whilst Damien et al. [3] suggests using social network analysis for stakeholders in distributed development.

3.2 When to Open Up

Reasons for opening up and releasing a software project, or parts of it, could be many, and often of a strategic nature [2]. On an upper management level, such decisions may be rare, and with time to analyze. In cases where firms do continuous development and exploitation of OSS, the question can be more common. Such lower level decisions may not have the time needed to be processed through traditional flows in large software producing firms. The pace of RE may vary between OSS communities, but in instances where the RE process is of a just-in-time character decisions may need to made quick. For firms having a maintainer’s role, feature requests from the OSS community could be reoccurring and developers and lower level managers need to know when they should implement such requests, reject or leave be for others in the community to act on. In the role of a contributor, this includes when to implement certain feature requests posted in the community, as well as if and when they should contribute their internal feature implementations. A feature’s differentiating value needs to be weighed against the cost of maintaining it internally, e.g. though patching each release of the OSS [25, 23]. Structuring such strategies would help developers prioritize and spend resources on implementing features which has the highest business value to the firm [25]. If not, this could be a notable cost, but also a strategic loss if differentiating parts are wrongly revealed.

Through selective revealing [9], certain parts of the code could be broken out and contributed. Separating the parts of differentiating value may however still prove difficult [25]. One way of tackling this issue would be to provide certain parts as enablers, while the innovative features are kept in-
A separate flow for innovative requirements is proposed so lines and sharp acceptance criteria imposed by the market. requirements flow are killed because they do not meet dead-

reason is that innovative features included in the normal

processes, workload accumulation, outdated software and

issues reported by Michlmayr et al. [14], which could be re-

added in time for product shipment to market [14]. Other

additional patchwork and differentiating features may be

intervals, firms can better adapt their internal plans so that

time-based strategy [14, 27]. With fixed release dates and

hybrid versions has been implemented. The latter performs

release when a set goals have been fulfilled, e.g. a certain

release strategies used by OSS communities can be classified

into feature-based and time-based. The former performs a

release process. The funnel itself represents the firm

architecture and other functionality. Often features are

analyzed and judged by the community based on a prototype

or finished implementation [20]. This again could be com-

municated in several ways, e.g. electronically or live at social

community gatherings [21]. Certain situations may require

pro-active judgment and contribution. In an example where

a firm wants a community to head in a certain direction and

add support for a certain functionality or environment [2],

the right way to go could be to incrementally contribute fea-

tures building up to the end-goal. Again comes the question

on how this should be done practically.

Hence, such practices and guidelines on how and when

firms should contribute or receive contributions need to be

integrated into the RE processes in order to streamline de-

velopment and keep it aligned with the firms business goals

and long-term strategy. Thereby, selective revealing or con-

tribution strategies [16, 25, 23] may link together the strate-

gic intents of the firm with its lower level RE processes to

better exploit its engagement with the OSS community and

maximize the innovation outcome.

3.3 Prioritization and Release Planning

Prioritization is an RE practice where the selection of re-

quirements for a certain release is decided. Release planning

is about packaging the right features into the right prod-

uct, in time with as high satisfaction among the stakehold-

ers as possible. In OI this area has had limited coverage

with some exceptions [25, 17] compared to the field of OSS

(e.g. [14, 27, 15, 5]). Michlmayr et al. [15] describes how re-

lease strategies used by OSS communities can be classified

into feature-based and time-based. The former performs a

release when a set goals have been fulfilled, e.g. a certain

set of features has been implemented. The latter performs

releases according to a preset schedule. Hybrid versions has

also been reported [27]. Literature has however favored the

time-based strategy [14, 27]. With fixed release dates and

intervals, firms can better adapt their internal plans so that

additional patchwork and differentiating features may be

added in time for product shipment to market [14]. Other

issues reported by Michlmayr et al. [14], which could be re-

frained with a time-based release strategy, are rushed imple-

mentations, workload accumulation, outdated software and
delayed releases.

In regards to OI, Nayebi et al. [17] proposes a decision sup-

port methodology called Analytical Open Innovation, which

considers information gathered through crowdsourcing from

customers and stakeholders, and analyzes their expectations.

This information can help adapt product composition and

release planning to predicted trends and anticipated user

expectations. Wnuk et al. [25] reports on how release plan-

ning is conceived as more challenging in an OI context. One

reason is that innovative features included in the normal

requirements flow are killed because they do not meet dead-

lines and sharp acceptance criteria imposed by the market.

A separate flow for innovative requirements is proposed so

that innovative requirements are able to mature in their own
pace. Once mature enough they would then be able to enter

the normal and more "harsher" requirements flow. Further

reason for release planning being extra complicated is due to

the lack of control over the process used in the OSS commu-
nities [25]. An example describes how it would have been

a better decision do adopt the OSS and sell it with mini-

mum changes, rather than have spent resources on adding

differentiating features, which is a common challenge in OSS

release planning [14]. This could imply a need for firms to

better understand the release processes used by OSS commu-

nities, as well as to propagate for more structured and

predictable processes.

Utilizing the overflow of information and access to new

data sources constitutes an opportunity to be exploited, as

exemplified by the analytical approach suggested by Nayebi

et al. [17]. The factor of a requirements innovativeness and

how this should be regarded in the prioritization and release

planning processes is another example where this could be

profitable. Establishing metrics that regards a feature’s in-

novation capability, output and performance [4] would be

helpful inputs to optimize the innovation outcome through

the prioritization and release planning processes. There are

frameworks that considers innovativeness in the release plan-

ning process (e.g. [18, 10]) but the area still lacks thoroughly

investigated and validated models, especially in regards to

the OI context.

4. FUTURE RESEARCH

Based on the contrasting between RE in OSS and OI in

the previous section, we formulate suggestions for future re-

search directions. To further frame and break down ques-
tions suggested, and help researchers consider the many an-
gles implied OI, we begin by defining a framing-model.

The OI model is often illustrated by a funnel [1], here

presented in Figure 1. The funnel itself represents the firm

internally, which in a SE context we define as the software

development process. This may in turn be illustrated either

as an iterative process, or just as one single development cy-

cle (e.g. from RE, design, implementation, test, to release).

The funnel is full of holes representing openings between

the firm’s development process and the open environment.
The arrows going in and out represent transactions and exchange

of knowledge between the two. This may for example con-

stitute of feature requests or bug reports, design proposals

or feature road maps, feature implementations or bug fixes,

test cases, complete sets of code as in plugins, components,

platforms or even products. From a more specific RE per-

spective this includes activities such as elicitation, prioritiza-

tion and release planning, which are performed interactively

between the internal and the open environment.

Firstly, based on Figure 1, we make a distinction between

an internal and external RE process. The internal concerns

the normal process connected to a firm’s internal product de-

velopment. The external concerns the one used in an OSS

community with which the firm interacts. This distinction

makes it clearer to illustrate how e.g. an internal release pro-

cess have to consider the external release process of an OSS

community, how the external stakeholder management may

differ from the internal, or how parts of the internal software

may be revealed to an existing or new OSS community, as

well as sourced externally from an OSS community.

A second distinction can be made between practices in-

ferred from the OI and OSS RE literature respectively. In
OSS RE literature, the scope has mainly been on a technical level with a starting point from seminal reports by e.g. Scacchi [20] and Erenkrantz [5]. In the OI literature, RE has had limited coverage with a few notable exceptions focused on release planning [25, 17]. Focus has instead been on how firms on a strategic level may influence or connect itself to OSS communities, and how OSS should be leveraged from a strategic point of view and integrated in different kinds of business models [24, 16]. Similar reports on the governance structures, how these function and should be managed are also reported in the gray area between OSS and OI. This distinction opens up for an interpretation of RE in OSS and OI on two levels, a strategic and an operational.

Finally, a third distinction can be made in regards to which direction the internal and external RE processes interact. A firm may e.g. reveal or outsource a feature to the OSS community (inside-out process), or collaborate with the OSS community on a feature (coupled process) [1].

These three distinctions are presented together in Table 1. Although all aspects of the framing-model may not be applicable in each case, it offers a tool to help angle and break down research questions to a possibly more concrete level. E.g. how a firm should align these processes with their business goals and communicate on a strategic level, against technically managing dependencies and risks of features internally and externally on an operational level.

Table 1: Conceptualization of RE in the field of OSS and OI.

|                | Internal RE process | Direction | External RE process |
|----------------|---------------------|-----------|---------------------|
| Strategic level|                     | ←→       |                     |
| Operational level|                   |           |                     |

The suggested research questions below should be further viewed from the framing-model presented in Table 1.

### 4.1 Stakeholder Management

**RQ A1** How to identify new and stay aware of present stakeholders in an open environment (e.g. [13, 12, 21])?

**RQ A2** How to continuously prioritize and judge importance of the stakeholders in an open environment (e.g. [8])?

**RQ A3** How to manage, adapt and act in shifting governance structures in an open environment with multiple stakeholders and fluctuating partnership types (e.g. feature-by-feature, project, and product)?

**RQ A4** How to leverage the requirements flows to position oneself strategically in an open environment [11]?

### 4.2 When to Open Up

**RQ B1** How to determine what artifacts (e.g. ideas, spillover requirements, IP, plug-ins, products) to open up and to what degree (e.g. selective revealing [9])?

**RQ B2** How to determine when the right moment is to open up the artifact for external involvement [22]?

**RQ B3** How to determine the way in which an artifact is to be developed (e.g. co-develop, outsource) and with/ by whom (e.g. single partners, groups or ecosystems) [22]?

### 4.3 Prioritization and Release Planning

**RQ C1** What release strategy is optimal under what conditions, and how should related practices and tools be adopted [15]?

**RQ C2** How should care be taken to involvement of other corporate stakeholders [14]?

**RQ C3** How should the internal release processes be tailored to fit with the OSS community’s in regards to innovative requirements? Specifically, how would a separate requirements flow fit and be structured in such a context [25]?

**RQ C4** How should risks and dependencies of features be managed and considered in an open environment [25]?

**RQ C5** How should innovativeness be considered as a decision factor (e.g. [18, 10])?

**RQ C6** What other decision factors may be considered relevant?

### 5. CONCLUSIONS

OI makes up a central opportunity as well as a challenge with which SE practices has yet to catch up, in order to fully accommodate and maximize the innovation outcome that firms aspire to achieve [26]. This includes RE, which is pivotal for a software development project to succeed. In response we build on and advance the proposed SE framework for fostering OI by Wnuk and Runeson [26], focusing on stakeholder management, when to open up, and prioritization and release planning. After performing a literature survey on OSS RE, we contrast it against recent finding
of OI in SE [16] to establish a current view of the area. Based on the synthesized findings we propose a research agenda along with framing-model to help researchers frame and break down their research questions to consider the different angles implied by the OI model.

We acknowledge that the literature survey may not give a complete view of the current state of RE in OSS and OI. However, we believe it can still explain current practices to a valuable extent and provide a valid basis for our proposed research agenda. Further, the proposed framing-model and research agenda are not to be seen as exhaustive but rather show suggested directions and help researchers break new territory in the field of RE in OI and OSS.

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