Practical Experiences in Designing and Conducting Empirical Studies in Industry-Academia Collaboration

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ABSTRACT

Context: More and more, software engineering researchers are motivated to solve real problems that bring value to industry. An example is the industry-academia collaboration described in this paper among *everis*, an IT consulting firm, and the GESSI research group at UPC. **Aim**: The goal of this paper is twofold: to evaluate the success of the collaboration, and to report the experience with conducting empirical studies in the industry and lessons learnt. **Method**: We evaluated our collaboration with an existing model for technology transfer, and performed a focus group discussion to identify challenges we have faced. **Results**: After initialization and alignment of the collaboration, a high maturity level has been achieved: we have obtained the first results in form of proposed solutions, scientific publications, and pilots run in real projects. In spite of this positive progress, further initiatives need to be undertaken in the last phases of the collaboration to achieve high degrees of maturity in deployment impact, industry benefit and innovativeness. **Conclusions**: Evaluating the collaboration has been positive, since we identified the next steps to be taken to achieve a high degree of technology transfer and innovation dissemination. We think it is a needed step in industry-academia collaborations in order to improve their success.

Categories and Subject Descriptors

D.2.11 [**Software Engineering**]: Software Architectures – domain-specific architectures

General Terms

Management, Experimentation.

Keywords

Industry–academia collaboration, empirical studies, empirical software engineering, case study, software architecture, software reference architecture, economic model.

1. INTRODUCTION

The conduction of empirical studies is increasingly growing in software engineering and specifically in software architecture. It has been claimed that "there is a vital need for gathering and disseminating empirical evidence to help researchers to assess current research and identify promising future research areas, and practitioners to choose appropriate methods and techniques for supporting the software architecture process" [2].

Under this scenario, the collaboration among industry and academia is a must. "It entails a mutual knowledge exchange between industry and academia. It is not about transferring results from research to industry; it is a joint venture with mutual learning. The researchers and their industrial partners form a joint team to address an industrial challenge. The research is conducted with close and regular contacts and discussions with the industrial partners" [17].

We describe an industry-academia collaboration, called "*Cátedra everis-UPC*" [4]. The collaboration is composed of three partners: the architecture group of *everis*, the Barcelona School of Informatics (FIB) at UPC, and our research group (GESSI) at UPC. The collaboration, which is funded by *everis*, started in May 2011 and will have duration of three years. Its goal is: "promoting training in information technology (IT) by conducting research, innovation, knowledge transfer and dissemination" [4].

Although the collaboration has other goals as training and recruiting students from FIB, in this paper we focus on the collaboration among *everis* and GESSI. The goal of the collaboration is to provide a solution to the current challenges that *everis* faces in Software Reference Architecture (SRA) projects, e.g., [7][8][9]. The goal of this paper is twofold: (1) to evaluate the success of the collaboration, and (2) to report the experience with conducting empirical studies in *everis* and lessons learnt.

First, we evaluated our collaboration with an existing model for technology transfer [15]. Second, we organized a focus group discussion to identify challenges we have faced.

The collaboration description is made by the two authors. We intentionally involved one person from each view (industry and academia) to reduce the bias of the report and to be as objective as possible. Still, we are aware of the self-report threat by authors.

Evaluating the collaboration has been positive, since we identified the next steps to be taken to achieve a high degree of technology transfer and innovation dissemination. We think it is a needed step in the conduction of any industry-academia collaboration in order to improve its success.

The paper is structured similarly to previous experience reports on industry–academia [14]. Section 2 describes a background of models for technology transfer. Section 3 reports the activities that have been performed since the beginning of the collaboration and Section 4 evaluates maturity of the collaboration with respect these research activities and the research results. Section 5 presents the lessons learnt that we identify in a jointly focus group among *everis* and GESSI. Finally, Section 6 concludes the paper and present future improvements to be performed.

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2. BACKGROUND

Empirical software engineering serves as support for transferring innovation [3]. The conduction of empirical studies is thus increasingly gaining attention to fulfil industry-relevant issues, as several recent experience reports show [16][17]. Another example is the collaboration of this paper, which relies on empirical studies to provide a solution to the current challenges that *everis* faces in SRA projects. An SRA is an architecture-centric approach to enable reuse and to standardize concrete software architectures of a class of software systems. The interested reader is referred to [7] to see the context of SRA projects in IT consulting firms.

In order to improve the body of knowledge on conducting empirical studies in industry, models for technology transfer have arisen, such as [5][15]. These models provide guidelines to conduct industry-academic research and evaluate it. On the one hand, Gorschek et al. [5] present seven sequential steps that they consider relevant and interdependent for overall transfer success (see Figure 1). On the other hand, Sandberg et al. define ten factors for successful projects [15]. Figure 2 shows the success factors in which the project depended on and the effects they had on the collaboration. In next two sections, we explain further and use these two models ([5] and [15]), in order to report and evaluate our collaboration. Both models are descriptive, i.e. they derive from experiences on performing industry-relevant research.

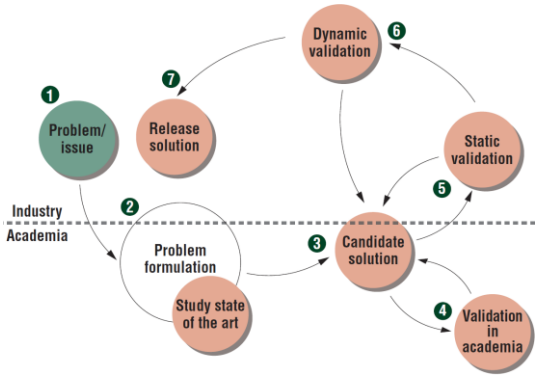

Figure 1. An activity model for technology-transfer in industry-academia collaboration, from Gorschek et al. [5]

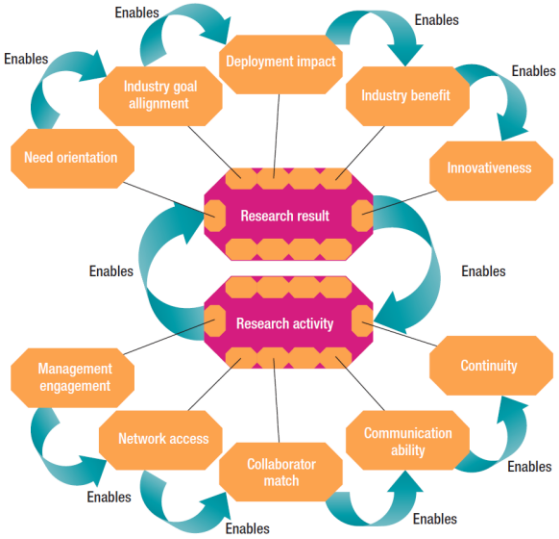

Figure 2. A relational model for industry-academia research, from Sandberg et al. [15]

3. THE COLLABORATION

In this section, we focus on the industry-academic collaboration between *everis* and GESSI. Although we did not follow the full Gorschek et al.'s process [5], we applied the first steps.

In order to show how the collaboration has been conducted and to analyze Gorschek's steps (see Figure 1) that need to be taken in the future, we report step by step our research since the beginning of the collaboration (May 2011) until the moment of writing this paper (January 2014).

Step 1: Identify potential improvement areas based on industry needs

When the collaboration was signed, the goal in the research area between *everis* and GESSI was: "to boost applied technological research related to software engineering in areas that will be identified as priorities within the sector". This goal was too broad and the so-called priorities needed to be identified.

In order to identify potential improvement areas, several joint meetings among *everis* and GESSI members were held between May and December 2011. During these eight months, the following activities were conducted. First, the collaboration team was created with two practitioners from *everis* and four researchers from GESSI. Second, the way of working was defined. Regular meetings were celebrated every one up to two weeks, minutes of meetings were written down, and a collaborative environment was set up to make collaborative work and exchange ideas, thoughts and material. Third, presentations lead by *everis*' employees were given to explain the current state of real projects and their challenges; similarly, presentations lead by GESSI were given to show our current research in software engineering. After these presentations, we discussed potential improvement areas in *everis*' projects and how the research conducted at GESSI could be of help. After several iterations, we decided to focus on SRA projects at *everis*. It is important to note that this improvement area (i.e., SRA projects) evolved over time, and other objectives that were previously considered were discarded as *everis* demanded (remarkably process monitoring and model-driven development to generate Create, Read, Update and Delete (CRUD) interfaces). Finally, *everis*-relevant needs were divided in two factors: organizational and technical [1]. This led to two Research Questions (RQ):

- RQ 1 (organizational): Is it worth for a possible *everis*' client organization to invest on the adoption of an SRA?
- RQ 2 (technical): How can an organization get corporate evidence that is useful for RA-related practices (e.g., defining the goals of an SRA, SRA design, SRA review, SRA use)?

The reader interested in the context of SRAs and how these RQs can deliver benefit to industry is referred to [7]. We do not focus here on SRA projects since it is out of the scope of the paper.

Step 2: Formulate a research agenda

The champions (one from *everis* and another one from GESSI) of the collaboration were defined since the beginning. They have been responsible of formulating the research agenda.

The first author of the paper started to work full-time in the collaboration since October 2011. Also, since November 2011 *everis* provided him an access card and a working space next to the managers at *everis*.

Once the RQs were stated, the first problem for the researchers was to learn the context of SRA projects at *everis* and the

vocabulary that practitioners used. It was a tough task. By April 2012, an internal report was created with this information and later published in [7]. When this point was reached, the two managers from *everis* were moved to other projects, given a company's policy about people rotation. A new manager became the contact person at the *everis* side, who is the second author of the paper. She has kept internal meetings with the champion at *everis* when necessary. Since then, she has had a long-term commitment to the collaboration. At the GESSI side, also two researchers move to other projects and one new researcher started to work in the collaboration. Since then (April 2012), the team is composed of one *everis*' manager that is GESSI's contact person at *everis* (plus the champion at *everis*, who is part of the upper management) and three researchers from GESSI (one of them is the champion at GESSI).

During this time, we designed the two main studies of the collaboration: on the one hand, case studies to calculate the Return-On-Investment (ROI) of SRA adoption; on the other hand, qualitative empirical studies to gather evidence about relevant aspects that could help in the design and evaluation of SRAs.

The contact person at *everis* helped in contacting multiple practitioners, and monitoring when new SRA projects were conducted to include them in the research.

Step 3: Formulate a candidate solution

From the beginning to the half of the second year of the collaboration (May-October 2012), we formulated the candidate solutions for our two problems.

On the one hand, we defined REARM: A Reuse-Based Economic Model for SRAs [8]. The goal was to provide means to calculate the ROI of SRA adoption with available data in SRA projects, which is an *everis'* need. The GESSI team played an important role in the creation of REARM by studying existing economic models of software reuse [12][13] and software architecture metrics [6] whereas *everis* provided evidence about available data in their company that makes REARM pragmatic and realistic.

On the other hand, we jointly identified relevant aspects for the design and use of SRAs. The GESSI team also studied the state-of-the-art about SRA-related practices and proposed the proper type of empirical studies to be conducted. In joint meetings, we discussed about the design of the interview guides and the questions of the online questionnaires.

Step 4: Conduct lab validation

Because of the characteristics of the RQs, little validation "inside laboratory" has been performed. On the one hand, for REARM, we needed to perform sensitivity analysis in order to test the robustness of its output and to search for errors by encountering unexpected relationships between its inputs and outputs. On the other hand, the qualitative empirical studies were validated to be aligned with existing literature.

Step 5: Perform static validation

In this step, we validated the two solutions devised for the RQs.

For the validation of REARM, we gathered data of one SRA project in an *everis*' client organization. We performed an internal report for the upper management and the champion in *everis* and the client organization that adopted the SRA. They validated the results, and provided the following feedback:

- They wanted to avoid the use of monetary terms in the calculation of the ROI in SRA adoption (which depends on the SRA vendor's price of hour) and preferred the use of hours invested and percentages as units of measure.
- The application of REARM was based on a small application based on the SRA, and they considered that the results would change and be better for medium and big applications.
- They highlighted that they were interested in considering the scenario of adoption of SRA vs. applications created from scratch. Specifically, they did not want to compare the current version of the SRA with a previous version (perhaps to avoid possible problems with their creators).
- They considered the results potentially useful for decision-making during SRA adoption.

For the validation of the semi-structured interviews and online questionnaires, two pilot iterations were performed and provided the following feedback:

- Inadequate vocabulary was used to refer to SRA projects' artifacts.
- Researchers did not understand the context of SRA projects properly, additional questions about the SRA project context were included.
- Questions that dealt with several variables disconcerted the interviewee and made the analysis more difficult. It is better to split them to cover only one variable.
- If a survey targets several stakeholders, their questionnaires should be designed having into account their knowledge and interest about architectural concerns.
- The questions should be designed to be easy to follow to avoid that participants reply in questions different than the one intended.
- In online questionnaires, it is recommendable to allow the interviewee to write any comments or clarifications in some field and also include an "n/a" option when necessary. Besides, a previous button is useful to make changes in prior questions.
- Contacting stakeholders from client organizations was harder than contacting interviewees from *everis*. This is mainly because *everis* requested the study, so they had a clear interest on it.

A negative point at this step is that, although we have contacted practitioners that participated in our studies to get feedback, we have not addressed widespread presentation of the candidate solution in *everis* or to the upper management.

Step 6: Perform dynamic validation (piloting)

In this step, the collaboration team conducted real pilot studies with the candidate solutions.

With regard to the economic model, we performed a business case for the adoption of an SRA in a public administration in Spain. The results are published in [8]. Currently, we are applying REARM in another SRA project in order to improve it and to validate its proper function.

With respect to the qualitative studies, we conducted a multi-case study in nine SRA projects. The aim was to gather relevant data about: benefits and drawbacks of SRAs (published in [9]), SRAs artifacts (published in [10]), architecturally-significant requirements and architectural decisions in SRA projects. Currently, we are analyzing the data gathered.

Step 7: Release the solution

The last step is to release the solution to show practitioners how it works and that it is better to use it rather than working as usual. After realizing the solution, practitioners should use it even without the intervention of the authors. This step has not been achieved yet. Nevertheless, it is vital to realize industry benefit. Section 6.1 describes the next actions to fulfil this step.

4. COLLABORATION EVALUATION

In this section we evaluate our industry-academia collaboration following the collaboration model of Sandberg et al. [15]. We evaluate the collaboration maturity and its management with respect to the factors stated by Sandberg et al. [15] (the former five factors relate to *research activities* whereas the second five, to *research results*, see Figure 2). To do so, the phase since the beginning of the collaboration to the present (January 2014) is considered. For each factor we use a Likert scale to assess maturity, with 1 representing low maturity, and 5 representing high maturity.

- **Research activity**

Management engagement: 5. The problem formulation was defined in the beginning of the collaboration after several meetings in which both representative of *everis* and GESSI were present. The two champions of the collaboration jointly manage the research, and have meetings when necessary (although not as frequent as the rest of members of the collaboration team).

Network access: 3. We have been able to contact best-in-class employees in *everis*. However, since *everis* is a consulting company, sometimes they did not have the competence to provide specific data because of confidentiality issues. Another challenge is to involve them in the data collection process when they are short of time (e.g., busy with other projects).

Collaborator match: 4. Upper management at *everis* is utterly interested in the results of the research, and practitioners have been willing to participate with researchers during the empirical studies.

Communication ability: 3. A very positive point is that GESSI has the option to communicate when necessary to *everis*' managers and other practitioners involved in SRA projects. On the other hand, once we have contacted other practitioners from *everis*, we have not followed their progress in SRA projects.

Continuity: 3. The topics defined in the beginning of collaboration as still being studied. Also, new client organizations are adopting SRA, so the context is still a current challenge. One representative from GESSI spent one day per week in *everis* from November 2011 to July 2013. From August 2013, he has only attended to meetings because of limited space in *everis*. This is not a big problem due to the geographic proximity of the two institutions and the flexibility of both sides for meeting organization.

- **Research result**

Need orientation: 4. The collaboration fully addresses a perceived real-life industry problem at *everis*.

Industry goal alignment: 3. Collaboration goals are aligned to current *everis* unit goals, while results are still in an early stage.

Deployment impact: 1. Results have not been deployed by *everis*' practitioners out of the collaboration yet. With the exception of pilots conducted by the joint team, results have not had an impact on practice.

Industry benefit: 2. Results are starting to be valuable to *everis* after the conduction of the first pilots. Yet, practitioners cannot see the results in daily work.

Innovativeness: 2. Internal reports and scientific publications are written by researchers and available by the entire collaboration team. Although they are not use widespread in *everis* yet, they have generated new ideas, knowledge, and publications for the research agenda of the collaboration.

5. LESSONS LEARNED

In the previous sections we reported the process that have been followed during the collaboration and evaluated the research activities and results under existing models for industry-academia collaboration. In this section we report the challenges that we have faced and dealt with in the "*Cátedra everis-UPC*". Also, we show the most important benefits that have been realized because of mutual collaboration.

Our approach to collect such data was a focus group, which it is considered a proven and tested technique to obtain the perception of a group of selected people on a defined area of interest [1]. The focus group encouraged structured discussions involving participants from the collaboration team. The discussion was largely free-flowing, and everyone has an opportunity to participate. Focus group discussion enables to identify how both industrial and academic partners feel and think about the issues of the collaboration [1]. We reported separately the issues brought by industrial and academic partners.

5.1 Challenges

Throughout the collaboration, we have encountered diverse challenges that required special attention. Next, we divide them inside four areas: general, industry, academia and research as defined by Wohlin in [17]. The goal is not to discuss reported challenges in the literature (e.g., [16][17]), but to discuss the challenges we experienced during the collaboration.

General Challenges. This group relates to challenges to the general relationship between industry and academia.

The general challenges highlighted by the *everis* side are described as follows. First, the *identification of goal* of the collaboration was successfully defined jointly in face-to-face meetings. We focused on solving an industry-relevant problem that could be solved with the expertise of GESSI. Second, *follow-up meetings* have been held regularly. The flexibility of both teams was vital for proper coordination.

Academic partners highlight the following success factors. First, *fluent and direct communication* when necessary among the partners is vital for progressing in the research. The communication between upper management of *everis* and the lead researcher at GESSI required special attention to evolve the goals to up-to-date industry needs. Second, the definition of a *work methodology* (e.g., use of a collaborative environment with a platform to share the results, meetings calendar, internal deliverables roadmap) enabled team work among people that were unknown before the collaboration.

Both partners highlighted the problem of the *changes of people in the collaboration team* due to policies on people rotation or any other event.

Industry Challenges. Challenges in this group concern specific issues to be addressed at the industry side of the collaboration.

Industrial partners uncovered as a weak point *not being leaders of an SRA project* being studied. It is vital to be close to the SRA project to give the most accurate information. In cases in which the *everis*' managers of the collaboration team were not involved in an SRA project or did not know the specifics of such project, it involved extra-effort of another practitioner who was highly involved in the SRA project to work in the collaboration. As a consequence, it is important that the practitioners who temporally join the collaboration have the *adequate role and are able to find the balance to dedicate time* in the research collaboration besides their SRA projects.

Researchers needed to face *difficulties while contacting practitioners* out of the collaboration since their availability is limited. Also, some candidate SRA projects could not be studied as deeper as desired since it was not always possible to *convince management of the everis' client organizations* that were involved in an SRA project. In our consulting context, it was a two-step job (first asking to *everis* champion and then to the client organization). The reasons why we did not study specific SRA projects were mainly confidentiality issues and bureaucratic issues (e.g., it was needed to ask for credential cards to access the client organization, insurance and so on for the researcher to observe or work in an SRA project).

Academia Challenges. In a similar way as for industry, there are some specific challenges related to academia.

At the *everis* side, they found a key issue the *experience of the researcher in SRA projects* (e.g., knowing the technologies being applied). A wrong perception of the context and low experience can jeopardize the results of the collaboration. We paid special attention to this issue in the beginning of the collaboration, in which researchers received tutorials and even developed a demo application based on an SRA to master this technological approach. Another solution, although we did not apply it, could have been to offer training to the researchers as it is done to new practitioners when they are recruited.

Researchers stated the following academia challenges. First, it is important to write *internal reports presenting results, which are not intended to end up as a scientific publication*. This way, deliverables are more relevant to the industry needs (e.g., executive summaries for managers, annual reports, and specific reports for *everis*' clients). Second, additional empirical studies should be conducted only to *understand the real context* in the industry. Third, the *results should be adequately presented to upper management* so that they continue to provide resources needed for taking the next steps.

Research Challenges. The actual conduction of the research comes with some challenges too.

Industrial partners stated the following challenges. First, the importance of *identify realistic sources of data*. In case of quantitative research and economic analysis usually happened that there was not as much historical and project data as needed. The search of data that did not exist, led to dangerous risks such as blocking points. Second, for the economic analysis *adequate scenarios should be designed*. Understanding the alternatives of SRA adoption enables better design of scenarios for decision-making. Third, the obtained *results need to be validated* to analyze that they correspond to the reality. This can be done by iteratively explaining experts the outcome of the research and studying their opinions until they agree that the results are realistic.

For the academia members, the research challenges are the following. First, a big risk is the *period required to start providing value* to the industry. The first results of the collaboration were delivered in the second year, and this situation is not common for industry, which may see that the research is not progressing. Second, in the collection of data our main challenge was how to *face with the incomplete information* that SRA projects may have. This is a serious threat to validate REARM, not just in post-mortem analysis, which could be something expected, but also with ongoing projects in which we experienced obstacles. Third, due to the diverse nature of SRA projects, it is difficult to create *repeatable techniques and results*, since not all SRA projects have the same data. Fourth, it is important to *present results to practitioners*. If this presentation is missed, two big risks potentially arise: the incorrect validation of the results and the no adoption of the techniques devised during the research.

In our opinion, this type of challenge (i.e., research challenges) is the most difficult to overcome. Research challenges highly depend on the context of the research (SRA projects in our case), and sometimes even require ad-hoc solutions.

5.2 Mutual Benefits from Collaboration

With respect to the benefits that each partner organization has received from collaboration, we highlight the following ones.

On the one hand, researchers helped practitioners to shape the results of SRA projects into publications and explicit architectural knowledge, since this task was difficult for them from their practical experience. This promotes innovation dissemination and technology transfer inside *everis*. Also, researchers provided feedback from existing research and other tools and techniques from the scientific community, such as experience in the conduction of empirical studies.

On the other hand, the GESSI members appreciate the willingness of *everis*' practitioners to collaborate in the research, which is much harder to achieve without formal industry-academia collaboration. Besides, the involvement of *everis* in the research enabled the possibility to make research to solve real problems in industry.

6. CONCLUSIONS AND FUTURE STEPS

"Collaboration between industry and academia supports improvement and innovation in industry and helps to ensure industrial relevance in academic research" [16].

This paper describes an industry-academia collaboration: the "*Cátedra everis-UPC*" [4]. First, we reported the steps of the collaboration following Gorschek et al. steps [5], and we evaluated our collaboration with an existing model for technology transfer [15]. Second, we held a focus group discussion to identify challenges and problems that we have faced in the collaboration as well as benefits.

On the one hand, after reporting and evaluating the collaboration, we can conclude that it has reached a high maturity. After two years and nine months of collaboration, first results could be seen in form of proposed solutions, internal reports, executive summaries, scientific publications, and pilots run in real projects. However, in order to improve the low levels of maturity in deployment impact and industry benefit, new actions need to be undertaken (see Section 6.1). On the other hand, challenges and lessons learned from our collaboration have been discussed. We believe that they are a good contribution to the body of

knowledge on conducting empirical studies in industry. Among the most important challenges are: identification of goal of the collaboration, fluent and direct communication, contacting and involving best-in-class employees, industrial experience of researchers, creating internal reports presenting results that are not intended to end up as a scientific publication, understanding the real context in industry, adequately presentation of results to upper management, identifying realistic sources of data, validation of results, facing incomplete information, devising repeatable techniques and results, and last but not least presenting results to practitioners.

6.1 Future Steps

Despite the aforementioned progresses, deployment impact, industry benefit, and innovativeness are still ongoing goals. The low level of maturity of these research results is the current main problem of the collaboration. We posit two reasons for this problem: the collaboration is still in an early phase, and the results are not yet articulated to provide lightweight support utilities (i.e., guidelines and artifacts) to support practitioners.

On the one hand, not realizing deployment impact, industry benefit, and innovativeness at early phases of industry-academia collaboration is a common situation, as reported in [5][14]. For this reason, we consider highly recommendable the evaluation of industry-academia collaboration in order to incrementally improve its success throughout all phases. On the other hand, we need to pay special attention to the packaging of the results in order to release a lightweight solution that can be used by practitioners without the intervention of the authors.

The evaluation of our collaboration has enabled to identify the next steps to be taken to achieve a high degree of technology transfer and innovation dissemination:

- Providing tool support to practitioners so that they can easily apply the envisaged economic model (i.e., REARM), as well as demo applications and case studies that use REARM as example.
- Reporting the evidence of the qualitative studies about benefits and drawbacks of SRAs, SRAs artifacts, architecturally-significant requirements in SRA projects and architectural decisions. This promotes innovation dissemination and technology transfer of SRA-related practices inside the company. Scientific publications are not a good approach for dissemination in industry. Instead, lightweight materials (e.g., presentations, executive summaries) are being created.
- Creating practitioners-oriented prescriptive support utilities (i.e., guidelines and artifacts). Besides, widespread celebration of workshops and training courses from the collaboration team to *everis*' practitioners involved in SRA projects should be performed.

7. ACKNOWLEDGMENTS

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