

A Case Study on the Application of an Artefact-Based Requirements Engineering Approach

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Abstract—[Background:] Nowadays, industries are facing the problem that the Requirements Engineering (RE) process is highly volatile, since it depends on project influences from the customer’s domain or from process models used. Artefact-based approaches promise to provide guidance in the creation of consistent artefacts in volatile project environments, because these approaches concentrate on the artefacts and their dependencies, instead of prescribing processes. Yet missing, however, is empirical evidence on the advantages of applying artefact-based RE approaches in real projects. [Aim:] We developed a customisable artefact-based RE approach for the domain of business information systems. Our goal is to investigate the advantages and limitations of applying this customisable approach in an industrial context. [Method:] We conduct a case study with our artefact-based RE approach and its customisation procedure. For this, we apply it at a software development project at Siemens following the steps of the customisation procedure. We assess our approach in direct comparison with the previously used RE approach considering possible improvements in the process and in the quality of the produced artefacts. [Results:] We show that our approach is flexible enough to respond to the individual needs in the analysed project environment. Although the approach is not rated to be more productive, we find an improvement in the syntactic and the semantic quality of the created artefacts. [Conclusions:] We close a gap in the RE literature by giving empirical evidence on the advantages of artefact orientation in RE in an industrial setting.

Keywords—Requirements Engineering, Artefact Model, Development Process Model, Case Study

I. INTRODUCTION

Requirements Engineering (RE) lays the foundation for successful software and system development projects regarding cost and quality (Broy 2006). The activities, which are performed as part of the RE process, aim at the discovery and specification of requirements that unambiguously reflect the purpose of a software system as well as the needs of all relevant stakeholders (Nuseibeh and Easterbrook 2000). The precise definition of requirements supports subsequent software development activities like architectural design or project management. As a software engineering discipline, RE contributes with precise requirements specifications to appropriateness and cost-effectiveness in the development of a system (Nuseibeh and Easterbrook 2000) and, thus, RE is an important factor for productivity and (product) quality (Damian and Chisan 2006).

An important step for companies towards RE excellence consists in the establishment of an RE reference process for a company-wide use among different projects. However,

companies are facing the problem that the RE process is highly volatile, since it depends on project influences from the customer’s domain or from process models used. Thus, volatile project environments restrict the appropriate application of the reference process at project level and complicate the decisions on what artefacts to produce in RE and on how to produce them in a syntactically consistent and complete manner. Another complicating aspect is that many influences arise during the execution of the process, as many aspects are not clear from the beginning of a project (Berenbach *et al.* 2009).

An observable consequence of the diversity in the project influences is that engineers often act solution-biased. This can lead to incomplete and inconsistent artefacts and thereby to disruptions in the development life cycle (Mendez Fernandez *et al.* 2010b).

Yet missing is an RE approach that provides:

- 1) a reference model (model blueprint) of the basic concepts to guide the creation of precise RE artefacts.
- 2) guidance for the customisation (tailoring) of the reference model at project level in response to project parameters, which affect the precision in the artefacts.

Artefact orientation seems an appropriate philosophy to provide such an approach. Artefact models define a blueprint of the results to be created and thereby abstract from processes, i.e., from the actual creation of specification documents by the use of particular methods in a particular sequence. Hence, as artefact models abstract from complex processes while capturing the basic concepts of an application domain, they should provide a means to tackle the problems stated above.

Problem Statement: Although the advantages of artefact orientation for RE are recognised (Mendez Fernandez *et al.* 2010a), no empirical evidence has been given yet on the application of artefact-based RE approaches in real projects.

Research Objective: We want to investigate the advantages and limitations of applying a customisable artefact-based RE approach at project environments. We developed such an artefact-based RE approach for the application domain of business information systems in a research cooperation with Capgemini Technology Services (TS) (Mendez Fernandez and Kuhrmann 2009). Because this approach is declared as the standard reference model for RE at Capgemini TS, we gained practical experience there, but we have little empirical evidence on how the approach finally tackles the stated problems beyond that. Hence, we want to investigate whether our

approach can be generally applied in real projects independent of the organisational culture of particular companies and whether it satisfies the need of a flexible RE process supporting the creation of precise results.

Contribution: In this paper, we contribute a case study on the application of a customisable artefact-based reference model for business information systems' analysis (short: BISA). For this, we apply our previously developed BISA approach in an industrial case study to analyse possible process improvements in a practical setting. We investigate the actual RE process and the resulting artefacts in a project at Siemens considering the development of a traffic control system. We apply our artefact-based approach in the same context and compare both our approach and the previously used one with respect to the performed process and the quality in the resulting artefacts.

II. FUNDAMENTALS AND RELATED WORK

We distinguish between an activity-based and an artefact-based philosophy. In both areas there exists a variety of contributions, which in turn can be structured into single approaches and comprehensive development process models. The latter abstract from the idealised project execution including a set of methods, milestones, roles, and artefacts. We subsequently discuss in both philosophies related work with respect to customisable approaches and conclude with an introduction into our previously published work.

A. Activity Orientation

Activity-based approaches rely on the philosophy of defining a concrete process by a set of methods to be performed in a particular order by a specific set of roles. Each of the methods provides a construction procedure to combining description techniques (Nuseibeh and Easterbrook 2000). These techniques are used to record the results into previously defined specification documents (or data sets) (Braun *et al.* 2005). Prominent examples are development process models, which are based on the *Software & Systems Process Engineering Meta-Model* (SPEM) (OMG 2008), such as the *Rational Unified Process* (RUP) (Kroll and Kruchten 2003). However, while such approaches offer the necessary elements to define a process, the customisation of the process to particular project environments is barely described and left to the expertise of project participants.

As a response to this shortcoming, *Situational Method Engineering* (Brinkkemper 1996) provides approaches to select and combine methods from a repository. This area can further be complemented by (*content-centric*) *Decision Support Systems* (see e.g. Regnell *et al.* 2001, Ngo-The and Ruhe 2005), which contribute approaches to select, classify, and rate a set of alternatives in the choice of methods (and description techniques) according to project parameters. Still, although the importance of a well-defined artefact model is recognised in this area (Foorthuis *et al.* 2008), artefacts and their dependencies are not in scope in available approaches. Braun *et al.* (2005) discover that only 50% of the analysed

approaches include an artefact description at all, while the approaches that include an artefact description reduce the artefacts to an optional outcome of the methods.

Activity orientation thereby does in general not guide in the creation of precise result structures, since available approaches emphasise the selection and combination of methods rather than their integration and application considering their syntactic compatibility and the consistency in the resulting artefacts (Arthur *et al.* 1997). The project-specific combination of methods is additionally hampered by the diversity in the project parameters and by the variability in the RE processes.

Hence, activity orientation does not satisfy the demand for an RE approach that guides in the creation of syntactically consistent artefacts while supporting the necessary flexibility during this creation. This is also reflected by the absence of empirical work in this area. Despite available case studies that analyse the application of isolated methods, further studies, which consider comprehensive development process models, put emphasis on the resulting process rather than on its customisation and application (Pedreira *et al.* 2007).

B. Artefact Orientation

A possibility to provide guidance in the creation of consistent artefacts in volatile project environments is to concentrate on the artefacts rather than on the way of creating them. This leads to process-neutral RE approaches following an artefact-based philosophy.

The idea of artefact-based approaches consists of defining a reference model of all artefacts that are an intermediate result of a development process. At project level, the actual process is then defined by agreeing on a set of artefacts to be created by a particular role and to be delivered when reaching a particular milestone. The diversity in the process definitions is thereby reduced to the dependencies between the artefacts themselves without having to take into account the complexity of differing processes. Artefact-based approaches are thereby meant to guide in the creation of precise results while offering the necessary flexibility during their creation.

However, there exist different views onto the structure and the syntax of artefact models depending on the intended purpose of the models. We can distinguish two major areas, in which artefact models are applied: development process models and model-based development approaches.

A prominent development process model, which relies on the artefact-based philosophy is the *V-Modell XT*¹, a German standard for IT development projects. The V-Modell XT defines an artefact (e.g. requirements specification) as a deliverable, which is coupled to a milestone, a role, and a set of activities. The included customisation approach describes mechanisms to apply the development process model as part of an initial project plan by selecting (according to a pre-defined set of project parameters) those artefacts, which are necessary in a project, similar to what is done with methods in decision support systems. The next steps consider the assignment of roles and milestones to the selected artefacts.

¹Available at <http://www.V-Modell-XT.de>

While the V-Modell XT and its customisation approach with its abstract view onto an artefact model ease process integration and customisation, they neglect, however, the domain-specific content in the artefacts.

Such content descriptions can be found, in turn, in the area of model-based development, in which artefact models (often referred to as “RE meta models”) capture the basic concepts and relations found in the description techniques used for a design methodology with respect to a chosen family of systems (Schätz *et al.* 2002). Thus, available approaches support the demanded precision in the creation of the artefacts.

At the same time, these artefact models become complex and thereby hamper the process integration and the customisation (by coupling the process elements to the artefact model).

C. Previous Work on Artefact-based RE

In (Mendez Fernandez *et al.* 2010a), we developed a meta model for artefact-based RE approaches, which, if instantiated for a particular application domain, unifies the advantages of artefact-based development process models and model-based development. We aimed at supporting a flexible process definition and at the same time offering guidance for the creation of precise results. For this purpose, we combined the two different views onto an artefact that have been treated in an isolated manner before. A *structure* view captures for each artefact type (e.g., “requirements specification”) the content items to be considered (e.g., “use case model”). Each artefact type is then coupled to the elements necessary to define a process, i.e., to roles, methods, and milestones. For each content item, we define the *content* view via the modelling concepts, e.g., the elements and relations of a use case model and different description techniques that can be used to instantiate these concepts, such as a UML activity diagram. The structure model thus supports the flexible process definition that we consider in the artefact-based customisation approach in Sect. IV. The content model supports the precision of the results during this customisation.

Figure 1 illustrates on its top both views taken by the meta model. The middle part of the figure illustrates an exemplary excerpt of the artefact model, which is part of the artefact-based RE reference model presented in the following Sect. III. The bottom part illustrates an exemplary outcome of customising the reference model, i.e., of creating project-specific exemplars of the reference model (see Sect. IV).

III. ARTEFACT-BASED REQUIREMENTS ENGINEERING REFERENCE MODEL

According to our understanding about artefact orientation in RE (see Sect. II-C), we developed an artefact-based reference model for business information systems analysis (BISA) in a cooperation with Capgemini TS. The development was performed over two years while we continuously evaluated the approach within 12 project environments. With the evaluation, we ensured the validity of the approach for the chosen application domain so that it correctly covers its basic concepts in a sufficiently complete manner.

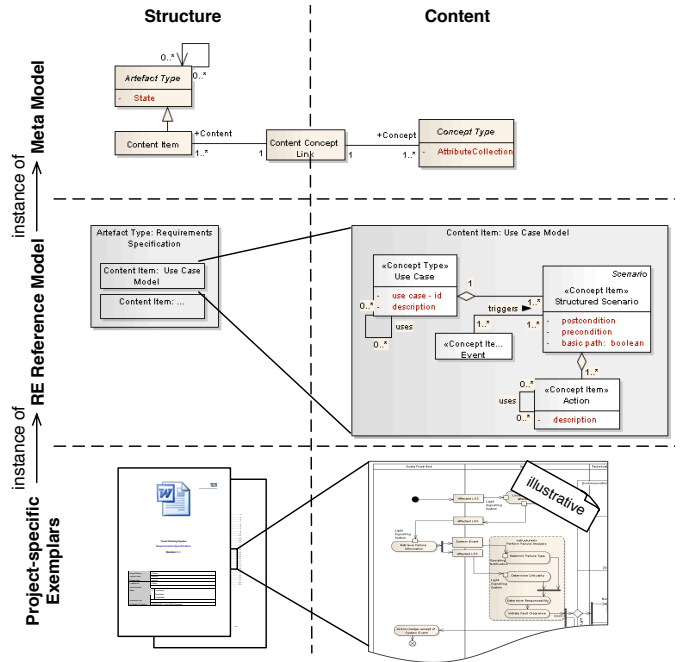


Fig. 1. Two Views onto an Artefact Unified by our Meta Model

The artefact-based BISA approach defines two artefact types as a domain-specific interpretation of RE: The *Business Specification* and the *Requirements Specification*. For each artefact type, we define:

- 1) *Methods and description techniques* as construction procedures, which describe how to create the content of the artefacts by the choice of a modelling language that has to incorporate the concepts and relations defined by the content model.
- 2) *Roles*, which define responsibilities.
- 3) *Milestones*, which define points in time on when to complete an artefact.

We subsequently give a brief overview of the two artefact types. Further elements of the BISA approach, such as a status model to support progress control, are not in scope of this paper and can be taken from (Mendez Fernandez and Kuhrmann 2009). Figure 2 illustrates selected concepts defined by the BISA approach with respect to their levels of abstraction and used modelling views. A level of abstraction is, in our context, a refinement stage over which the content in the artefacts is refined and / or decomposed. We use differently coloured shapes to illustrate to which artefact type the depicted concepts relate and omit in the figure (for reasons of complexity) the dependencies between the concepts.

A. Business Specification

The business specification contains all goals (statements of intent), capabilities (behaviour), restrictions, and conditions that affect the business of a company without describing requirements towards the underlying systems.

In particular, the concepts used in the business specification describe long-term objectives of a company and the desired

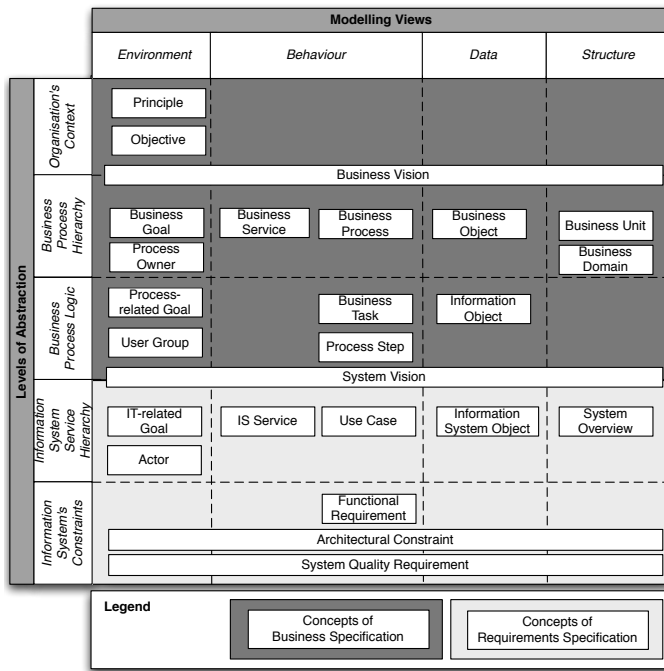


Fig. 2. Artefact Model of BISA in a Nutshell

business processes. We decompose goals over different levels of abstraction. Goals motivate the decomposition of business processes to a sequence of atomic process steps performed by user groups. In relation to the decomposition of behaviour models, we model the interchanged data and the organisation's structure. For describing structure, we distinguish between the description of business units and business domains. The latter groups logically related business processes for which one process owner is responsible.

B. Requirements Specification

The requirements specification comprehends demanded properties of information systems, organisational restrictions on the development process, and restrictions on the integration, that all shall be accomplished by a development project according to the content of the business specification.

In particular, we make use of concepts for specifying how the business process shall be realised by a particular system. For this, we make use of use cases and services. The first specifies interaction scenarios between actors (logically representing user groups) and the system as a whole. In contrast, services describe a logical representation of a use case, not necessarily involving actors or concrete sequences of interaction. Regarding the data modelling view, we use information system objects as a system-side representation of the information objects, which are interchanged in the business processes. The system overview captures the context of a system in interaction with surrounding systems. Finally, we decompose behaviour models to further concepts, including architectural constraints and system quality requirements, which constrain a system and its environment in its properties and conditions by means of metrics and values.

IV. ARTEFACT-BASED CUSTOMISATION APPROACH

The customisation approach guides the creation of the artefacts at project level in response to individual project characteristics. Figure 3 illustrates on its left side the actual approach and on its right side how the single steps relate to decision support.

To enable this decision support in an artefact-based context, we introduce a project repository. In contrast to activity-based decision support systems, however, we characterise projects by the impact of project parameters on the creation of artefacts, instead of indirectly characterising projects by parameters impacting the choice of methods for producing the artefacts. The parameters' impact can *argue* for the creation of certain content items or *hamper* their creation. For instance, if user groups are unavailable, this condition can hamper the creation of use case models and at the same time argue for the specification of risk status lists. An exemplary set of project parameters can be taken from our previously performed field study (Mendez Fernandez *et al.* 2010b). By the use of such a project repository, we can support project participants in making certain decisions. To support the transfer of made decisions backwards from projects to the project repository, we introduce the additional artefact *BISA Diary*. In this artefact, we capture for each content item in the artefact, project parameters, which affect the item's completeness and corresponding decision that has been taken. This way, we can use a project repository in multi-project environments to re-use organisation-specific experiences and decisions.

Regarding the actual customisation approach, we distinguish two stages. The first stage considers the instantiation of the BISA reference model during the *Initial Project Set-Up* to initially define a process frame, similar as done in the V-Modell XT (see Sect II-B). Within this initial set-up, we elaborate the project background and create initially agreed on exemplars of the artefacts. We choose for each artefact the desired document structure and include the initial content, which is already available. We assign the roles, define the milestones, and set-up of the tool infrastructure. This step is performed during initial workshops, e.g., during a kick-off workshop. The second stage considers within this (planned) process frame the dynamic content creation of the artefacts during project execution, which results in a probable *Project-specific BISA Execution Strategy*. This dynamic content creation is performed in response to project parameters that affect the completeness of the artefacts. We decide on how to proceed for the content of each business domain and document our decisions within the BISA diary. For instance, user groups might be unavailable for negotiating interaction scenarios in the context of the business processes of the business domain "Customer Administration", for the domain "Sales" they could be available. In that case, we could decide to document services for the first business domain instead of use cases and document this decision in the BISA diary.

The outcome of the project-specific BISA execution strategy are artefacts in a certain quality and the documented

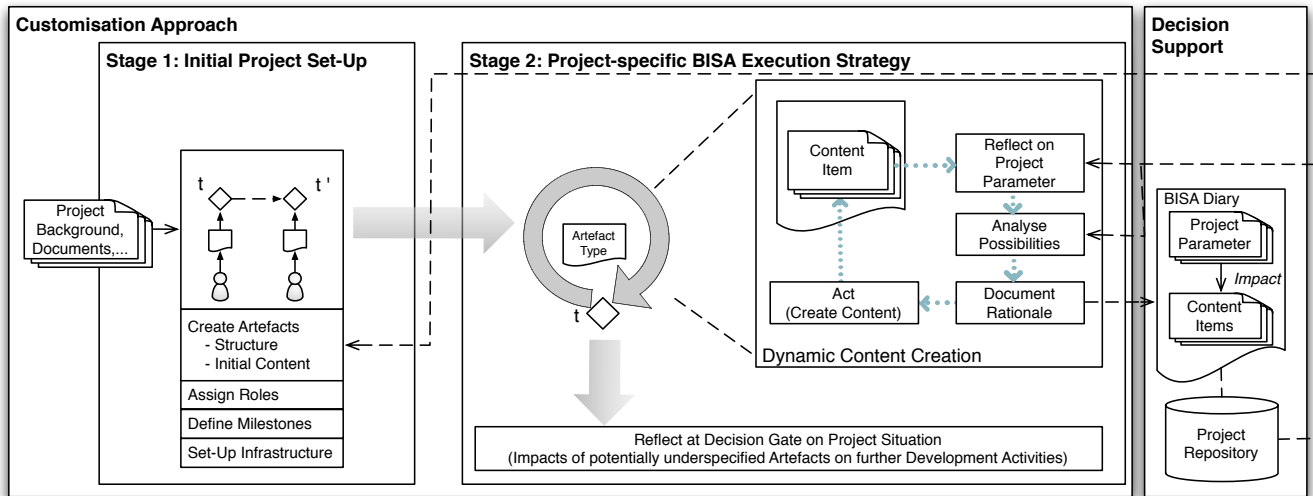


Fig. 3. Customisation Stages Considered by the BISA Approach

decisions. In contrast to activity orientation, we now are able to objectively assess the quality of the artefacts with respect to the artefact-based reference model. We can check whether the artefacts are underspecified, i.e., syntactically incomplete or inconsistent with respect to the reference model. When reaching the milestone of the corresponding artefact, we can reflect on potentially underspecified artefacts and their consequences on further development activities that rely on those artefacts.

Therefore, due to the notion of underspecified artefacts we can objectively decide on what risks the quality in the results implicate and, thus, achieve guidance in the creation of precise results and of the made decisions that have lead to those results.

V. CASE STUDY DESIGN

We organise the case study according to Runeson and Höst (2009). After defining the goal and the research questions of the study, we describe how we select the case and the subjects. Finally, we describe how we collect and analyse the data, before concluding with a discussion on the validity procedures.

A. Research Questions

The goal is to investigate the advantages and limitations in the application of our customisable artefact-based RE approach in an industrial environment. For this, we formulate three research questions.

RQ 1 *Does the artefact-based approach improve the usability of the RE process?*

One aim of artefact orientation consists in the flexibility of the process, i.e., its usability in differing project environments while leading to reproducible results. Thus, our first research question aims at analysing whether we can achieve an improvement in the usability of the RE process.

RQ 2 *Does the artefact-based approach improve the syntactic quality of the created artefacts?*

Once we analysed the actual process for creating the artefacts with respect to individual project influences, we want to know whether the created artefacts are of higher syntactic quality due to the underlying model-based philosophy of our approach.

RQ 3 *Does the artefact-based approach improve the semantic quality of the created artefacts?*

Finally, for implementing the requirements it is not only important that the syntactic quality is high, but also that the requirements are stated correctly and sufficiently detailed, i.e., the semantic quality is high. Thus, we want to know whether the approach also improves the semantic quality of the created content.

B. Case and Subjects Selection

We apply the artefact-based reference model and the corresponding customisation approach to a software development project and repeat the RE process for a part of the system under consideration. Both the case and the subject selection are opportunistic, because we need a real development project and access to its participants and documentation. Nevertheless, we choose a project that considers a similar application domain as the one for which BISA has been developed but differs in its industrial context. Especially, we are interested in an evolving system, because Capgemini mostly replaces legacy applications completely by new systems.

To select a representative part of the system, we hold a discussion between the industry participants and researchers. We select a set of business domains (logically clustering potential processes and use cases) for which corresponding stakeholders are available. This way, the approach can be conducted entirely including the creation of the business and the requirements specification. We define three main groups of participants as study subjects:

- 1) *Industry participants*: Experts from industry responsible

for performing the (baseline) RE phase of the system development project under consideration. Ideally, they have different viewpoints on the requirements specification, e.g., product managers and developers.

- 2) *Researchers*: Researchers familiar with the BISA approach take the role of requirements analyst and support the customisation procedure at the industry partner.
- 3) *External reviewer*: In order to achieve an unbiased assessment of the produced specifications an external reviewer (not involved in the actual process) will be called in.

C. Data Collection Procedures

The collection of the data for the case study comprises the participation of the researchers in the RE process as well as a concluding assessment of the performed process by internal and external reviewers. We first perform the process according to the customisation approach as part of a series of workshops between the researchers and the industry participants. Afterwards, we assess the process and the produced artefacts in direct (benchmark) comparison to the legacy process previously used in the company. The industry participants do an *internal assessment*. An external reviewer is called in especially for conducting an independent *external assessment*.

1) *Requirements Engineering Workshops*: We conduct the steps of the BISA approach in a series of workshops, which are organised according to the customisation approach (Sect. IV). In these workshops, the researchers and the industrial participants are present while the researchers take the role of requirements analysts.

Initial Project Set-Up: At the kick-off workshop, the researchers present the BISA reference model and the customisation approach. We customise the BISA reference model to initially set up the project. We select the artefacts to be created, decide on a preferable document structure, assign the roles, define the milestones for when to complete the artefacts, and finally agree on the used tool infrastructure. Then, we discuss a set of specification documents, which we use as an initial input. This input includes a description of the business goals, the relevant stakeholders and the business domains. We use the latter to organise the subsequent workshops.

Dynamic Content Creation: As part of the second customisation stage, we perform a workshop for each of the relevant business domains. In each of the workshops, we discuss the business processes of a domain and corresponding use cases. We use both the processes and the use cases to initially sketch the corresponding vision documents (business vision and the system vision). After each of the workshops, the researchers further specify the contents on the basis of the given information, i.e., they complete the use cases or infer probable system quality requirements, which are presented and approved at the beginning of the next workshop.

Approval and Acceptance: After having created the content for each of the identified business domains, i.e., when reaching the agreed milestones, we jointly review the artefacts and the industry participants can reject or accept them with the possibility to demand further changes.

2) *Assessment*: As a preparation for the assessment, each industry participant and the external reviewer review both the previously documented specification documents and the BISA artefacts (specifications and BISA diary). As a guideline for the reviews, the reviewers get a questionnaire that will later be used in the interviews. We perform these interviews with the industry participants as a group interview (directed by the researchers). The interview with the external reviewer is performed in isolation.

The goal of both interviews is to answer the questionnaire, which includes a set for different assessment criteria. Since the external reviewer has no insights into the actually performed process, the assessment criteria in his questionnaire is mostly reduced to the ones that consider the quality of the produced results. For each assessment criteria, we define a closed and an open question. In a closed question we ask for the agreement to a given statement. It can be answered on a Likert-scale from $1 = I$ strongly disagree to $8 = I$ strongly agree. We deliberately choose an 8-point scale to avoid that the interviewees check the middle. In the open question, we ask for their expert opinion, in which the interviewee answers as free text. This open question may also be used for additional remarks and explanations regarding the selected grade on the Likert-scale. The condensed questionnaire with the statements of the closed questions is shown in Table I.

To answer *RQ 1*, we ask for information on the execution of the process, respectively the customisation approach. Since only the industry participants and researchers were present while performing the process, only the industry participants will answer this part of the questionnaire. An exception is given by the assessment of the sustainability of the approach, which is analysed by the external reviewer (only he can analyse whether the process is reproducible on the basis of given specifications).

We answer *RQ 2* by assessing the syntactical structure of the specifications. This includes the structuring of the artefacts into topics, which, e.g., provide an easy understanding of traceability from high-level requirements to detailed ones. We additionally investigate the content in the artefacts with respect to cross-references between different content items, which serve, e.g., as background information or as a rationale.

Regarding *RQ 3*, we assess the actual content of the produced specifications. To rate the minimality and the completeness of the requirements, deep domain knowledge is necessary whereby only the industry participants can answer these two questions.

D. Analysis Procedures

Due to the low number of participants for the questionnaire, statistical hypothesis testing is not applicable. Therefore, we present the results of the closed questions as a radar chart. We analyse the answers to the open question qualitatively to further explain the answers of the closed questions and to discuss the differences between the legacy process and BISA-specific one.

TABLE I
QUESTIONNAIRE FOR THE ASSESSMENT (CONDENSED)

	Criteria	Statement
RQ 1	Ease of use Sustainability Effectivity Flexibility Productivity Structuredness	The approach is clear and understandable. The process and the taken decisions are reproducible. All information and requirements are used in design and management activities. The approach supports a flexible process in response to individual project characteristics. The perceived productivity was high. The RE process is systematic.
RQ 2	Syntactic Consistency Complexity Syntactic Completeness Syntactic Minimality Modularity Traceability Ease of Perception	Elements in the specifications are used consistently. The complexity in the cross-references is low. All syntactic elements needed to specify the requirements are given. There are no unnecessary syntactic elements in the specifications. The specification is organised in modules, separated according to certain topics. Each requirement has a rationale. The specifications are well-suited to be understood by people not involved into the process.
RQ 3	Unambiguity Testability Semantic Completeness Semantic Minimality Semantic Consistency	The requirements are stated unambiguously. The fulfilment of each requirement is measurable / testable. All stakeholder needs are reflected by the specifications. There are no needless requirements in the specifications. There are no contradictory statements in the specification.

E. Validity Procedures

To increase the reliability of the statements of the industry participants, and thus the internal validity, we perform a group interview. Through the interaction between the group members, memories and experiences of the participants are stimulated. This way, they can produce insights that would be less accessible without this technique. Furthermore, the different group participants serve as quality control, because extreme opinions are filtered out by the participants (Lindlof and Taylor 2002).

Additionally, researcher triangulation is used to increase internal validity: in addition to the assessment of the specifications by the industrial participants (internal assessment), the assessment is done by a researcher not participating in the whole process (external assessment).

Moreover, methodological triangulation is used, by asking both open and closed questions. Through the open questions the interviewees can express their opinion more freely. On the other side, the closed questions force them to agree on one statement.

To mitigate the threat of a bias toward the BISA specification by the external reviewer, he is not involved in the study prior to the actual assessment. He is not allowed access to further documents, like background information, to ensure his judgment relies only on the produced artefacts.

VI. CASE STUDY RESULTS

After the description of the cases and subjects, we describe the results and structure them according to the research questions. For reasons of confidentiality, we can not give detailed information on the (baseline) RE approach, the system under consideration, or illustrate the exact content of the produced (BISA) specifications.

A. Case Description

The case study is conducted with a department of Siemens AG. This department develops a traffic control system

(TCS). The system is a hybrid of geographically distributed embedded controllers in traffic lights and a central information processing and monitoring system. To stick to the application domain for which the BISA approach has been developed, the analysed sub-system is such a monitoring system of the TCS.

The TCS is in production for more than 30 years, while each year a new release is developed. In each of those releases, Siemens conducts a development project with an RE process, which takes three months. The reference process definition, the *Siemens Reference Process House*, underlies the activity-based philosophy. The development process used in our case is specialised according to the particular project needs and characterised by a set of milestones and corresponding methods, which are used to document the requirements in natural language into previously structured, self-contained *Excel Specifications*.

The BISA specifications were documented in *Microsoft Word* documents, which we structured according to the (artefact) structure model. To record the content of the BISA specifications, we extended the UML tool *Enterprise Architect* with a plugin, which is based on the content model, i.e., we developed an UML profile and defined individual modelling shapes to specify, e.g. business processes and goal graphs in conformance to the artefact model.

For the content of the specification documents, we consider the activities of three different business domains, which are supported by the monitoring system: *Planning*, *Operations*, and *Maintenance*. During operations, an operator is provided with communication and controller states by the system. In case of anomalies, these states are analysed and an initial fault clearance is initiated. Furthermore, the operators perform statistical analysis over a chosen period of time, and in case of traffic accidents they provide juridical evidence about the actual status of the corresponding traffic lights. Figure 4 illustrates an exemplary excerpt of the resulting requirements specification (see Sect. III), which contains the use case overview for the business domain “Operations”.

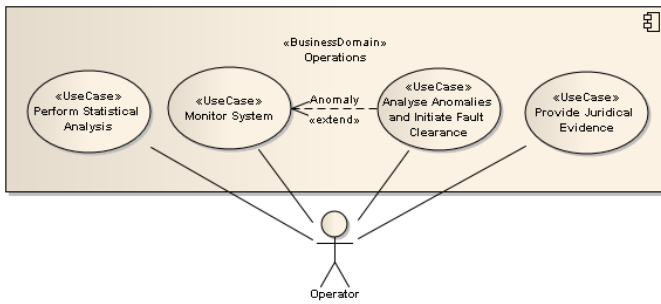


Fig. 4. Exemplary (Operations) Use Cases

Regarding decision taking during the content creation, we documented each decision and the underlying project parameter in the BISA diary (see Sect. IV) created with Microsoft Word. As a whole, the diary contains 26 project parameters. For instance, we documented the mentioned use cases in natural language, because of their low (functional) complexity. A further project parameter which took effect on the content creation was, e.g., “timeboxing”, which we used as a rationale for documenting business services instead of detailed business processes.

B. Subject Description

As described in the subject selection, there are three groups of participants. In the group *industry participants* there are two roles, which were assigned to three employees of Siemens AG:

The *Product Manager* is responsible for defining the requirements for the control and monitoring system from the customer/user viewpoint. He represents potential customers. The *Project Lead* is responsible for broader management activities of the development department. Regarding requirements engineering, he is responsible for negotiating the requirements with the product manager.

The group of researchers consists of three software engineering researchers from the Technische Universität München with a special focus on requirements engineering. Daniel Mendez Fernandez is the main developer of the BISA approach. Klaus Lochmann and Birgit Penzenstadler also have detailed knowledge on the BISA approach and participate in the RE workshops.

As external reviewer acts Stefan Wagner of the Technische Universität München, who also has knowledge about the BISA approach. He was, however, not involved in the earlier steps of the case study.

C. Analysis Results

Figure 5 illustrates the results of the assessment as a radar plot, depicting the ratings of the closed questions.

In the following, we describe the results with respect to our research questions taking into account the answers made in the open questions.

1) *Usability of the Process (RQ 1)*: The BISA approach achieves an improvement of the usability in the process. The industry participants judged the BISA approach as *easier to*

use due to its flexibility and its guidance given by the artefact model. In the interview, they explained that BISA defines a clear customised process. It needs, however, guidance during its customisation whereby deep knowledge in the approach (“skills”) is needed. The legacy process to produce the Excel specification is more ad-hoc, since it offers no guidance with respect to individual project situations.

As the customisation approach gives guidance on structuring elicitation workshops according to logically related requirements clusters (business domains), they also saw an increase of the *structuredness* in the approach. The industry participants also stated an improvement in the *effectivity* as they noticed a higher acceptance ration in the requirements, i.e., less requirements had to be re-adjusted and negotiated with corresponding architects after acceptance.

Regarding the *productivity*, they concluded that the BISA approach is more heavy-weight due to the artefact-based reference model, which demands for the specification of several topics in a certain syntactic quality. Still, they see this artefact-based approach to be beneficial if a previously unknown system is specified from scratch. If all participants have already a common understanding of the problem space, however, – like in the department where the case study was conducted – then a more lightweight approach is also adequate. Therefore, they judged productivity to be equal in both approaches.

Regarding the *sustainability* of the approach, the external reviewer stated that the BISA process could be reproduced. The reason is to be seen in the BISA diary, which documents all the made decisions leading to the created artefacts. In contrast to the BISA approach, he could not reproduce the legacy process, because he was only confronted with the produced Excel specification.

2) *Syntactic Quality of the Artefacts (RQ 2)*: Both the internal and external reviewers assessed the *syntactic quality* of the specifications. The internal reviewers judged the syntactic completeness to have slightly increased in BISA. They explained that in the Excel specification they are able to define columns for all information needed. The use of further description techniques like UML, however, is not possible. On the other hand, Excel offers filtering functions that can be used to aggregate needed information. BISA offers far more syntactic elements and proposes different description techniques for representing requirements, which are better suited for certain kinds of information.

This is also reflected by the judgment of the external review, who stated BISA to be substantially better regarding syntactic completeness. This is because the artefact model and the supported description techniques in BISA are more specific and therefore easier to understand to external people. This assessment is supported by the statement of the internal reviewers that the syntactical elements in Excel are inconsistently used whereby the meaning of the syntactical elements often remain unclear.

Both reviews judged that there are less unused syntactic elements in BISA. The external reviewer found out that for example the column *state* in Excel is never used. One

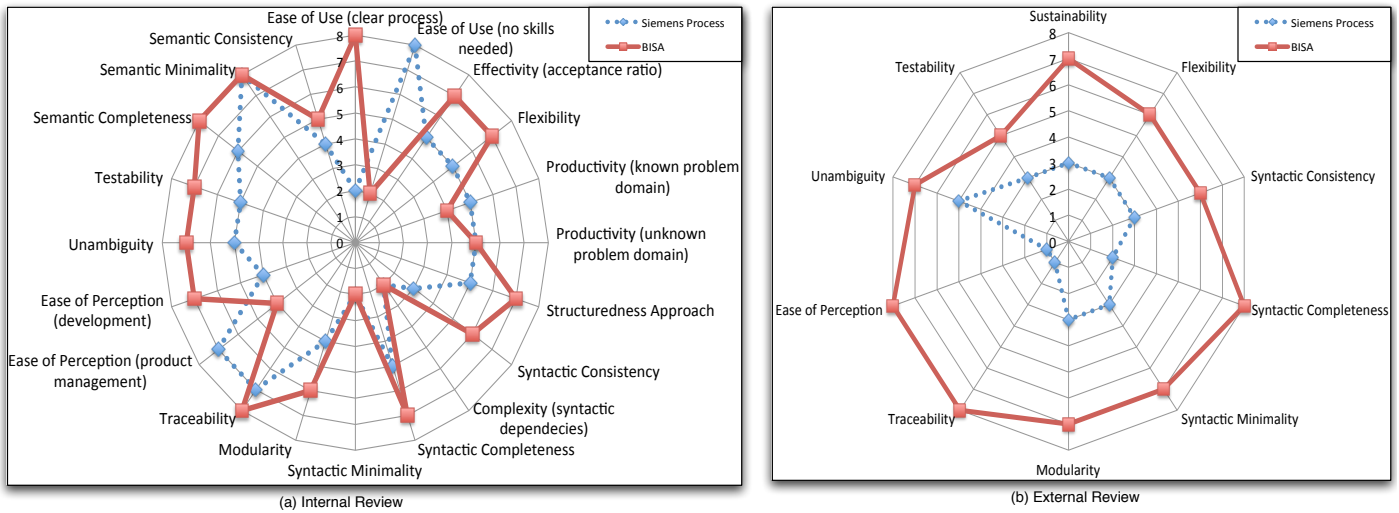


Fig. 5. Analysis Results Shown as Radar Plots

reason for the syntactic minimality of BISA in contrast to the elements given by the Excel specification is that the BISA artefact model has been customised.

The judgment of the *traceability* is different for both reviewers. The internal reviewers see a marginal increase in traceability in BISA, while the external reviewer assesses the traceability in the Excel specifications with the lowest grade and that of BISA with the highest. The reason for this difference can be found in the explanations the internal reviewers gave in the interview. They acknowledge that there is no rationale for requirements given in Excel. They know, however, that there are other documents in their company where the rationales are implicitly given. They further acknowledge that background information, like goals, are specified in BISA more comprehensively and structuredly. The difference in the judgment is further explained by the comments of the external reviewer. He could not discover any rationales for requirements in Excel, thus he judged the traceability with the lowest grade. In BISA however, he sees a clear top-down hierarchy given by the refinement notion in the artefact model (see Fig. 2 on page 4) whereby implicitly necessary domain knowledge has to be made explicit.

3) *Semantic Quality of the Artefacts (RQ 3)*: Both the internal and external reviewers judged the *testability* of the requirements slightly better in BISA than in the Excel specifications. The testability, as well as the unambiguity, are improved in BISA, because the artefact model proposes a strict content model including several requirements attributes, such as acceptance criteria. Furthermore, both reviewers noticed that the free text formulations in the Excel specifications allows for more freedom in interpreting them. Again, the artefact model reduced this freedom and gives more guidance to create precise requirements. The internal reviewers, however, judged the resulting contents to be more perceptible by the development department rather than for the product management, since the content model demands for detailed

specification of, e.g., architectural constraints.

The *semantic consistency* could be judged only by the internal reviewers, because of their domain knowledge. They rated the semantic consistency for the BISA specifications slightly higher than for the Excel specification, because the dependencies in the artefact model are more suitable to find inconsistencies. The *semantic completeness* was stated to be higher in the BISA specification for a similar reason. The artefact model and the customisation approach supports a structured discussion of business needs and requirements, which would not have been considered before.

D. Evaluation of Validity

Regarding construct validity we see the threat that the used questionnaire might not adequately represent the research questions. Although the questionnaire was developed jointly by all researchers participating in the study, it cannot be ensured that there are no topics missing. In addition, the answers of the participants are inherently subjective. Through the intensive discussions of the answers and different view points of the participants we could improve their objectivity.

The internal validity could be threatened by a bias towards the BISA specification of the reviewers, because the external reviewer was involved in the original development of the BISA approach. This threat is only minor for the internal reviewers, because they are comparing their legacy specification with the BISA specification. Another threat to the internal validity could be that different efforts were spent in creating both specifications. The better completeness and traceability of the BISA specification, for example, could be explained by more effort dedicated to it. However, this threat is seen as minor, because both approaches got the same rating on productivity. As explained in the validity procedures, a researcher triangulation was done to mitigate reliability threats. When comparing the results of the internal and external assessment, we can see that the answers are differing, but have the same trend. This fact strengthens our confidence in the collected data. Also the

methodological triangulation supports the internal validity. No major contradictions between the explanations given in the open questions and the rating of the closed questions could be found.

Regarding external validity, the major concern is the generalisability of the results, because we conducted this particular case study only in one company. From the viewpoint of the industry and research participants, however, a representative part of the system under consideration was selected.

VII. CONCLUSION

Due to the missing agreement on artefact orientation, we developed a meta model for this philosophy (Mendez Fernandez *et al.* 2010a). Based on this meta model, we developed a reference model for business information systems' analysis including a customisation approach, which transfers the principles of decision support to the new artefact-based philosophy (Mendez Fernandez and Kuhrmann 2009). In this paper, we applied our approach in a case study at Siemens to investigate the advantages and limitations of artefact orientation.

Summary of Conclusions: The proposed artefact-based approach shows to be suitable for use in practice. The study participants rated it as flexible enough to respond to their individual project needs, especially in comparison to their current activity-based approach. They only did not feel to be more productive, but acknowledged in particular an improvement in the syntactic and also the semantic quality of the created artefacts.

Relation to Existing Evidence: To the best of our knowledge there does not exist any reproducible case study that compares activity-based approaches and artefact-based ones, whereby the case study at hand closes this gap in literature.

Limitations: Inherent in case study research is the limitation to a small number of cases and subjects. We cannot generalise the strength of the approach, since it is intended for the domain of business information systems. For software with substantially different characteristics it might perform not as well. Achieved improvements also depend on the existing approach on site. In other contexts, in which model-based requirements approaches are already used, the improvements may be smaller. Finally, one discovered limitation is that the approach seeks rather an application in unknown problem domains, e.g., reflected by the productivity.

Impact/Implications: In addition to considering more unknown problem domains, the establishment of artefact orientation is, in general, an elaborate task (see Sect. III introducing the development of the BISA approach). However, taking RE as a critical process that is mostly driven by uncertainty it is important to support a flexible process design leading to high quality results. We could show that artefact orientation is promising to satisfy exactly those demands. We showed, e.g., an increase of both the syntactical and semantical completeness and consistency of artefacts while those were flexibly and reproducibly created in response to individual project needs.

From a practitioner's perspective, the results show that the efforts necessary to establish an artefact-based RE approach should be justified by the resulting benefits. From a researcher's perspective, it seems promising to further investigate the field of artefact orientation in order to integrate available methods for different application domains.

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