Towards CMMI-Compliant Business Process-Driven Requirements Engineering

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***Abstract*—Modeling of business processes has been both recommended by academia and adopted by industry for elicitation of system requirements. Software process maturity models are also relevant in industry, and compliance with them is a major concern for many organizations. Therefore, business process-driven requirements engineering approaches should aim to comply with those maturity models, and how the approaches comply or not should be determined. However, no work has addressed these issues properly. This paper proposes a compliance analysis, based on a maturity model, of business process-based requirements engineering approaches as a first step to tackle these issues. This type of analysis allows practitioners to know if a specific approach meets their needs, and researchers to identify room for improvement in approaches in order to try to increase their industrial acceptance. As an example, the compliance of an existing approach with the requirements development process area of CMMI-DEV is analyzed. The analysis has allowed us to determine the characteristics of the approach that meet CMMI-DEV, and to identify improvement opportunities so that the approach fulfills further industry needs. Furthermore, the results of the analysis apply to other approaches.**

Keywords- Business Process Modeling, Requirements Engineering, CMMI, Software Process Quality, Quality Assessment.

I. INTRODUCTION

An information system (IS) for an organization must support its business processes. Consequently, the need of modeling business processes for elicitation of system requirements has been widely recognized in academia (e.g., [14]). This is also in line with current practice in industry, in which business process models are often used for requirements elicitation and specification [10], and for conceptual modeling [4].

Another important issue in many organizations nowadays is compliance with software process maturity models [17] (hereafter referred to as maturity models). By following these models, organizations aim to be more efficient and to improve the quality of the products developed, as well as to meet market and stakeholders' needs.

Given the importance of maturity models, we consider that business process-driven requirements engineering (RE) approaches should aim to comply with them in order to meet industry needs. If an approach is not compliant, its adoption in industry may be hindered. Therefore, the compliance of an approach with maturity models should be determined. However, no existing work has dealt with this challenge properly yet.

We advocate that existing business process-driven RE approaches must be analyzed on the basis of maturity models as the first step towards addressing this challenge. As an example, this paper presents the compliance analysis of a specific approach [5] (hereafter referred to as BPRE4OO, Business Process-driven RE for Object-Oriented conceptual modeling) with the requirements development (RD) process area of CMMI-DEV (Capability Maturity Model Integration for Development) [15].

The analysis is performed by using an assessment method based on SCAMPI (Standard CMMI Appraisal Method for Process Improvement) [16]. As a result of the analysis, the characteristics of BPRE4OO that meet the requirements of the RD process area have been determined. Improvement opportunities have also been found to make BPRE4OO fully compliant with the process area. As will be discussed further, the results obtained also apply to other business process-driven RE approaches.

The contribution of this paper is twofold. First, practitioners that aim to comply with CMMI-DEV (or another maturity model) can benefit from the analysis by adapting it to detect weaknesses on other RE approaches in relation to the maturity model that they follow. Second, the analysis can be very useful in academia for identification of room for improvement in existing business process-driven RE approaches and thus for the discovery of further research areas. Furthermore, the approaches can be improved and their industrial acceptance may increase by using this type of analysis as a reference.

The rest of the paper is organized as follows. Section II presents background work. Section III describes the assessment method proposed for compliance analysis. Section IV analyzes BPRE4OO compliance with the RD process area. Finally, Section V summarizes our conclusions and discusses some future work.

II. BACKGROUND

This section briefly describes business process-driven RE and presents CMMI-DEV as background work of the paper. Related work is also reviewed.

A. Business Process-Driven Requirements Engineering

Overall, business process-driven RE approaches are characterized by aiming to elicit and specify requirements for (and thus develop) an IS so that the system supports and fits the business processes of an organization. They focus on understanding the business goals that an IS should support, creating business process models in addition to a data model

and functional specifications, and supporting new ways of executing business processes [1].

Among the existing business process-driven RE approaches, BPRE4OO has been chosen as an example of approach to be analyzed because it has been designed and developed by the second, third and fourth author. Therefore, it is the approach that we know in more depth. In addition, and unlike other approaches, BPRE4OO defines a detailed RE process for its application, which facilitates its analysis.

BPRE4OO was developed in the context of OO-Method [13], an approach for automatic software generation from object-oriented conceptual models. As a consequence, requirements specification is linked to conceptual modeling.

The RE process proposed by BPRE4OO consists of four stages (Fig. 1): organizational modeling, purpose analysis, specification of system requirements, and derivation of object oriented-diagrams. The process assumes that a problem (or need) exists in an organization. Such a problem could be solved by an IS, and its resolution may change the way business processes (modeled in the form of BPDs [12], business process diagrams) are executed.

Fig. 2 shows an example of extended task description (ETD), which is the style proposed for specification of system requirements. More information about the stages is provided in Section IV, and more details can be found in [5].

In addition to BPRE4OO, some examples of business process-driven RE approaches and the models that they propose are:

- EKD [2]: goals model, business rules model, concepts model, actors and resources model, business process model, and technical components and requirements model.
- ARIS [14]: organization view, data view, function view, product/service view, and process (control) view.
- Communication Analysis [9]: system/subsystem level, process level, communicative interaction level, usage environment level, and operational environment level.
- UML-based approaches (e.g., [8]): vision view, process view, structure view, and behavior view.

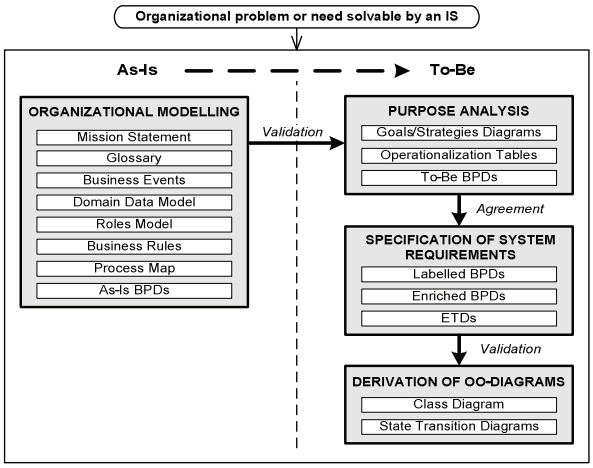

Figure 1. Stages and artifacts of BPRE4OO

Extended Task Description: **CAR RENTAL**

Business process: Car rental	**Role:** Office employee
Subtasks: Choose a car, Check whether a customer is new or not, Record customer data, Search for customer data, Fill contract, Choose extras, Take deposit, Print contract details	
Triggers: - **Preconditions:** - **Postconditions:** -	
Frequency: 10 times per day during winter season; 40 times per day during summer season **Critical:** Days on which a holiday period begins in summer season	

Input		Output	
Domain Entity	**State**	**Domain Entity**	**State**
Car	Ready	Rental contract	Open
Customer (1)	-	Car	Rented
Extra	Ready	Customer (2)	-
		Extra	Rented

Business Rules
- The insurance of a car must be valid during the rental period
- A car cannot be rented if it has more than 300000 km

User Intention	System Responsibility	Information Flows
Normal interaction		
	1. Show cars	← $_1\{$ Car / make + model / $\}_n$
2. Select a car		→ Car
	3. Show customers	← $_1\{$ Customer / ID number / $\}_n$
4. Select a customer		→ Customer (1)
5. Introduce rental contract information		→ Rental contract / contract number + current date + current time + office + return date /
	6. Show rental contract details	← Rental contract / contract number + current date + current time + office + return date + rental cost + extras cost + VAT + deposit + total cost / + Car / make + model / + (Customer (1) / ID number / | Customer (2) / ID number /) + [$_1\{$ Extra / name / $\}_n$]
Alternatives		
(New customer) 4.a.1. Introduce customer data [5]		→ Customer (2) / name + surname + ID number + address + city + telephone /
Extensions		
	(Extras request) 5.a.1. Show extras	← $_1\{$ Extra / name / $\}_n$
5.a.2. Select extras		→ $_1\{$ Extra $\}_n$
(Deposit payment) 5.b.1. Introduce deposit amount		→ Rental contract / deposit /

Quality attributes
- When an office employee selects a car, no other office employee will be able to select the same car (*Functionality/Suitability*)

Figure 2. Example of ETD

Although we cannot argue it in depth and provide many details due to page limitations, all the business process-driven RE approaches share many characteristics. Therefore, most of the results presented in this paper, specifically for BPRE4OO, also apply to those other approaches. Nonetheless, a detailed compliance analysis of them would be necessary to more precisely show how they comply with the RD process area.

B. CMMI-DEV

CMMI-DEV [15] is a guide to implement a continuous process improvement for developing products/services. It is the maturity model most frequently adopted nowadays [17].

CMMI-DEV provides two representations for the assessment of a software process: staged, which assesses the maturity level of the whole development process of an organization, and; continuous, which assesses the capability level of individual process areas that are selected based on organizational business goals. This paper is related to the continuous representation because only the RD process area is considered for compliance analysis of BPRE4OO. This process area has been selected because it is the one that focuses on requirements elicitation and specification, as business process-driven RE approaches do.

In the continuous representation, achievement of a capability level depends on goals and practices (decomposition of goals) of two types: specific, which are only related to a particular process area, and; generic, which are related to several process areas.

From the assessment of practices and goals, the capability level of a process area can be classified on a scale from 0 to 3 (see [15] for details). The higher is the level, the greater is the likelihood of increasing the quality of the final product and of more predictable schedules and budgets. BPRE4OO will be assessed against the capability level 1 of the RD process area. This level is considered the basis for improvement initiatives in a specific process area.

C. Related Work

Several authors have analyzed the compliance of traditional and agile software development processes with CMMI and its ancestor CMM (e.g., [11]). However, results from these works are not completely applicable to business process-driven RE approaches. As mentioned above and discussed in [1], these approaches have characteristics that differentiate them from others.

In addition, at least one of the following weaknesses are found in works that deals with other software development processes: analyses are less detailed and not based on SCAMPI [16] (a method to objectively assess the development process of an organization according to the requirements of the process areas of CMMI); analyses are based only on compliance with activity descriptions, not requiring documental evidence or based on partial evidences; lack of explicit, objective criteria for analysis; lack of details about the rationale behind the analyses, or; non-provision of solutions to fill in the gaps found in the analyses.

Even though we have found some works related to compliance of business process-driven RE approaches with CMMI, they fail to deal with this issue properly. They do not explain in detail how an approach complies with the model, where the approach should be adjusted for compliance, and where the approach conflicts with the requirements of the maturity model. The most relevant related works found are [3] and [18].

In [3], a RE process in the context of system family engineering is proposed. The authors claim that the process is compliant with the RD and requirements management process areas of CMMI. However, an explicit mapping identifying the evidences to attest the compliance is not presented. In [18], a RE process for workflow management systems is proposed and a compliance mapping in relation to the RD process area is presented. However, the work does not provide all the evidences required by SCAMPI. The way of performing the assessment is also less systematic and rigorous than the method proposed in this paper.

Lastly, a software process framework based on a goal-oriented RE approach (*i**) and on a model-driven development approach has been proposed in [7]. Such a framework is compliant with the RD process area of CMMI. However, this work did not address compliance of business process-driven RE approaches. Therefore, the framework should be tailored in order to fit the distinctive characteristics of these approaches.

III. A SCAMPI-BASED ASSESSMENT METHOD

SCAMPI deals with the consolidation of evidences (e.g., documents and affirmations obtained from interviews) related to the execution of a software process in actual projects. An assessment team uses the evidences to support the attribution of grades to practices, goals and, finally, to the evaluated process areas.

Although a typical SCAMPI analysis is performed using artifacts from actual projects, we have defined an assessment method based on available documentation about BPRE4OO because the approach is not yet applied in industrial scale. In addition, an analysis based on documentation makes it possible to obtain results independent from any organizational context, and draw conclusions without influences from the environment in which the approach is used. We also consider that this assessment method corresponds to a realistic scenario. If an organization that follows or plans to follow CMMI-DEV considered the possibility of adopting BPRE4OO, then it would probably first consult documents about the approach to initially evaluate its degree of compliance. The largest and most detailed existing document about BPRE4OO is [5].

The assessment is performed in a bottom-up way, from practices to goals, and two types of evidence are considered:

- Affirmations: statements described in the process confirming or supporting implementation of a practice.
- Artifacts: evidences mentioned in the process description and indicative of the work being performed; they represent either the primary outputs of a practice or a consequence of implementing a practice.

Both affirmations and artifacts are SCAMPI concepts, but they have been re-defined and adapted for the assessment method proposed in this paper.

For characterizing the level of implementation of a practice, four grades are used:

- Fully implemented: evidences are present and judged to be adequate for demonstrating the implementation of a practice, and no weaknesses are found.
- Largely implemented: evidences are present and judged to be adequate for demonstrating the implementation of a practice, but some weakness is found.
- Partially implemented: although some information suggests that aspects of the practice are implemented, some or all the data required are absent or judged to be inadequate, and some weakness is found; or the data supplied to the assessment team present conflicts (i.e., certain data indicate that a practice is implemented and other that it is not) and some weakness is found.
- Not implemented: some or all the data required are absent or judged to be inadequate, the data supplied do not support the conclusion that the practice is implemented, and some weakness is found.

Based on the grades defined for a practice, each specific or generic goal is graded as:

- Satisfied, if and only if all the associated practices are graded as either largely implemented or fully implemented, and the aggregation of the weaknesses of the practices does not have a significant negative impact on goal achievement, or;
- Unsatisfied, if at least one of the associated practices has a grade different from largely or fully implemented.

Finally, the capability level of a process area is defined from the grades defined for the goals. For example, to comply with level 1, a process must satisfy the generic goal associated with this level. Such a goal has only one generic practice, which requires that all the specific goals associated with the process area must be satisfied. If one of the specific goals is not satisfied, then the process area is considered to have capability level 0. For capability levels higher than 1, other generic goals associated with the specific and the previous levels must be satisfied, which impose further requirements.

IV. Compliance Analysis of BPRE4OO with the RD Process Area

The purpose of the RD process area is to elicit, analyze, and establish customer, product and product component requirements. It addresses all customer requirements and not only product level requirements. A compliance analysis between the capability level 1 of the RD process area and BPRE4OO is presented in this section. It uses an instance of the assessment method described in Section III.

The compliance analysis was performed as follows. Firstly, the first author performed an initial analysis on the basis of the publications about the approach. He has experience in CMMI consulting and as a member of assessment teams [6], what increases the validity of the analysis. Secondly, the second, third and fourth authors, who know BPRE4OO in depth, reviewed the analysis in order to identify possible flaws or misinterpretations. They also discussed the results with the first author to validate them.

For each specific goal associated with the RD process area, the purpose of each corresponding specific practice is presented, the practice is mapped to affirmations and artifacts of BPRE4OO, and the corresponding grade is given. After grading all the specific practices of a specific goal, the goal is graded. Finally, a summary of the results is presented, where the whole process area is graded and improvement suggestions are discussed.

A. Analysis Details

Three specific goals must be satisfied to comply with the capability level 1 for the RD process area.

SG1) Develop Customer Requirements. This goal addresses the collection of stakeholder needs, expectations, constraints and interfaces, and their transformation into customer requirements. The goal is decomposed into two specific practices.

SP1.1) Elicit Needs. Functional and non-functional requirements are discovered to express stakeholder needs, expectations, constraints and interfaces throughout the product lifecycle.

- Affirmations: BPDs are used as main artifacts for elicitation of system requirements. In the purpose analysis stage, stakeholders' goals are determined on the basis of the organizational problem to be solved.
- Artifacts: As-Is BPDs, statement of organizational problem or need, goals specified in the goals/strategies diagrams and To-Be BPDs.
- Grade: Largely implemented. Non-functional requirements and technical requirements related to other product lifecycle phases are not explicitly elicited.

SP1.2) Transform Stakeholder Needs into Customer Requirements. Requirements elicited from stakeholders (including customer and technical roles) should be consolidated, analyzed regarding missing information and presence of conflicts, and prioritized to some criteria. Requirements related to verification and validation can also be elicited.

- Affirmations: In the goals/strategies diagrams, system features that can fulfill stakeholders' goals are modeled as strategies. The effect of strategies on business processes is determined in the operationalization tables.
- Artifacts: As-Is BPDs, statement of organization problem or need, goals/strategies diagrams, operationalization tables and To-Be BPDs.
- Grade: Partially implemented. Requirements from some stakeholders (e.g., programmers) are not considered; and requirements prioritization, conflicts resolution and constraints affecting verification and validation are not addressed.

Conclusion: SG1 is unsatisfied because SP1.2 is partially implemented.

SG2) Develop Product Requirements. This goal addresses refinement and elaboration of customer requirements in order to develop product and product component requirements. Some of the practices associated with this goal can be performed during or in conjunction with a design stage. The goal is decomposed into three specific practices.

SP2.1) Establish Product and Product Component Requirements. Product and product component requirements are expressed in technical terms that can be used for design. They are derived from customer requirements and may also address other lifecycle phases. Modifications on customer requirements must be reflected in these derived requirements.

- Affirmations: In the specification of system requirements stage, To-Be BPDs are labeled according to the system control on them. Enriched BPDs are then modeled and system requirements are elicited from them. System requirements are specified by means of ETDs.
- Artifacts: labeled BPDs, enriched BPDs and ETDs.
- Grade: Partially implemented. Requirements changes are not tracked, there is no explicit traceability between all customer requirements and product requirements, and derived requirements are not explicitly established.

SP2.2) Allocate Product Component Requirements. The product components requirements (functional and non-functional) are allocated to product components.

- Affirmations: In the derivation of object-oriented diagrams stage, a class diagram and state transition diagrams are derived from ETDs. These diagrams define structural and behavioral abstractions for the classes (regarded as components) responsible for meeting the corresponding product requirements.

- Artifacts: ETDs, and class and state transition diagrams.
- Grade: Largely implemented. Allocation of non-functional requirements to product components is not addressed and traceability between product and product components requirements is not explicitly documented.

SP2.3) Identify Interface Requirements. Interface requirements between functions, objects or other logical entities are identified.

- Affirmations: In the specification of system requirements stage, data requirements are specified in the ETDs by means of its input and output domain entities and of the information flows that an IS and its users will exchange. In the derivation of object-oriented diagrams stage, classes, methods, attributes, associations and state transitions diagrams define the interface among the classes identified from the ETDs.
- Artifacts: ETDs, and class and state transitions diagrams.
- Grade: Fully implemented.

Conclusion: SG2 is unsatisfied because SP2.1 is partially implemented.

SG3) Analyze and Validate Requirements. This goal addresses requirements analysis and validation. Its specific practices support the development of the requirements in SG1 and SG2. Some of the practices associated with this goal can be performed during or in conjunction with a design stage. The goal is decomposed into five specific practices.

SP3.1) Establish Operational Concepts and Scenarios. Operational concepts (i.e., general descriptions on how the entities are used) and scenarios (i.e., detailed sequences of events that make explicit some of the functional or quality needs) are identified and maintained.

- Affirmations: In the purpose analysis stage, To-Be BPDs reflect the effect that the IS will have on the business processes. In the specification of system requirements stage, scenarios are specified in the ETDs by means of user intention and system responsibility, which are also constrained by quality attributes.
- Artifacts: To-Be BPDs and ETDs.
- Grade: Fully implemented.

SP3.2) Establish a Definition of Required Functionality and Quality Attributes. A definition of the required functionality and quality attributes is determined and maintained.

- Affirmations: Quality attributes are identified in the specification of system requirements stage and documented in ETDs. In the derivation of object-oriented diagrams stage, once ETDs have been specified, object-oriented diagrams are derived from them.
- Artifacts: ETDs, and class and state transition diagrams.
- Grade: Fully implemented.

SP3.3) Analyze Requirements. The requirements for one level of the product hierarchy are analyzed to determine if they are necessary and sufficient to meet the objectives of higher hierarchy levels.

- Affirmations and artifacts: not available.
- Grade: Partially implemented. There is not an explicit verification process neither tracks of its execution. Nonetheless, artifacts of the approach are generated systematically from others previously created, thus verification is implicit.

SP3.4) Analyze Requirements to Achieve Balance. Requirements are analyzed to balance stakeholder's needs and constraints (e.g., cost, schedule, performance, functionality, priorities, reusable components, maintainability and risk).

- Affirmations and artifacts: not available.
- Grade: Not implemented. No further information suggests the implementation of the practice.

SP 3.5) Validate Requirements. Requirements are validated to ensure that the resulting product will perform as intended in the end-user environment.

- Affirmations: In the organizational modeling stage, stakeholders validate the As-Is BPDs. In the purpose analysis stage, goals/strategies diagrams are created in a collaborative way between the system analyst and the stakeholders. In the specification of system requirements stage, the To-Be BPDs are labeled according to the system control on them, and the labeling is agreed upon with the stakeholders. The labeled BPDs are enriched by specifying those sequence flows that are always executed consecutively, and the stakeholders validate the diagrams. Then, system requirements, elicited from the enriched BPDs and from the stakeholders, are specified by means of ETDs, and validated by the stakeholders. The diagrams produced in the derivation of object-oriented diagrams stage are created from artifacts previously validated by the stakeholders (transitive validation).
- Artifacts: not available.
- Grade: Partially implemented. Although the validation is transitive, artifacts explicitly related to the validation activities are not kept.

Conclusion: SG3 is unsatisfied because SP3.3 and SP3.5 are partially implemented and SP3.4 is not implemented.

B. Summary and Improvement Suggestions

According to the assessment described in the previous subsection, the RE process of BPRE4OO has capability level 0. However, most of the weaknesses found can be easily solved. For this purpose, several improvement suggestions have been determined and are summarized in Table I. The table also shows the stage of BPRE4OO and the specific practice of the RD process area affected by the improvement.

Most of the improvements are simple adjustments in the RE process related to explicit modeling and documentation of evidences for some system analysts' actions and decisions. All these improvement suggestions also apply to the rest of business process-based RE approaches reviewed in Section II.A. This means that the approaches would need at least these adjustments to comply with the RD process area. For some of them, a concrete RE process would also have to be defined.

By tailoring BPRE4OO with these improvements, it is possible to turn the grade of all the specific goals of RD into satisfied. As a result, and as explained above, BPRE4OO would reach the capability level 1 for this process area. However, the improvements should be implemented in a new version of BPRE4OO and used in actual projects in order to confirm the effectiveness of the changes.

TABLE I. IMPROVEMENT SUGGESTIONS FOR BPRE4OO

Improvement	Stage	SP
Inclusion of mechanisms for elicitation of non-functional requirements and of technical requirements related to other product lifecycle phases.	Purpose analysis	SP1.1
Consideration of more types of stakeholders and of constraints regarding verification and validation, and explicit requirements prioritization and conflict resolution.	Purpose analysis	SP1.2
Record of requirements changes and inclusion of mechanisms for traceability between customer requirements and product requirements and between technical requirements and customer requirements.	Spec. of system reqs.	SP2.1
Analysis of the impact of non-functional requirements on product components and inclusion of mechanisms for traceability between product requirements and product component requirements.	Deriv. of object-oriented diagrams	SP2.2
Generation and record of evidences related to verification and validation activities.	All	SP3.3 SP3.5
Consideration of balance analysis between stakeholder's needs and product constraints.	All	SP3.4

V. CONCLUSIONS AND FUTURE WORK

Business process-driven RE approaches that do not fulfill the constraints imposed by a maturity model may not be adopted by an organization that aims to comply with the model. In this paper, we have proposed a maturity model-based analysis as the first step to deal with this issue.

A SCAMPI-based method has been presented to perform a compliance analysis on the basis of the documentation of an approach. Such documentation would correspond to the initial information to assess an approach and study its adoption. The method has allowed us to identify improvement opportunities on BPRE4OO that may increase its industrial acceptance, and can allow practitioners to know if the approach meets their needs and researchers to identify room for improvement.

The overall purpose of the paper was to emphasize the general need of performing a maturity model-based analysis of business process-driven RE approaches, not only of BPRE4OO. The gaps found in BPRE4OO can be generalized to other approaches. For example, all the business process-driven RE approaches are more focused on business requirements than on system requirements and on customer stakeholders than on technical stakeholders, have weaknesses in mechanisms for traceability and for validation and verification, and lack explicit requirements balance analysis. Although the analysis has been presented for BPRE4OO and CMMI-DEV, it can be adapted to other maturity models and to other business process-driven RE approaches.

We consider that this paper is a starting point for several future works. Other business process-driven RE approaches should be analyzed in detail for assessment and for comparison with BPRE4OO, and specific ways to implement the improvement suggestions for BPRE4OO must be determined. Compliance of BPRE4OO and CMMI-DEV should also be analyzed in actual projects. Finally, compliance analysis of the integration between BPRE4OO and OO-Method with other process areas and capability levels of CMMI-DEV is planned.

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