Toward a Goal-Oriented Methodology for Artifact-Centric Process Modeling

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Keywords: Process Management System, Process Modeling Methodology, Artifact-Centric Process Modeling, Process Monitoring, Traceability.

Abstract: Process management systems aim to enable a flexible yet systematic control of the execution of a process on the basis of its model. Therefore, a process model should encompass all necessary information for achieving the monitoring goals on the operational process. Up to this time, the research in process modeling has tended to focus on developing process modeling languages to represent process models. However, it lacks concrete guidelines for modelers to systematically define such models with the adequate details to enable an effective control of process execution. In this study, we address this lack by proposing a goal-oriented methodology for systematically modeling processes. Our methodology is dedicated to Artifact-Centric Process Modeling (ACPM). ACPM is an emerging approach that combines both data and process in a holistic manner, thus it's more suitable to model complex unstructured processes. We illustrate the proposed methodology by applying it practically to model a portion of the Rational Unified Process (RUP) with the intention of enhancing traceability at execution time.

1 INTRODUCTION

A process is defined as a set of connected tasks, that performed by process participants in order to carry out a predetermined specific goal. Process Management Systems (PMS) offer a great support for coordinating process tasks by automating the workflow based on the process model. Typical usage of a PMS is process monitoring, which enables observing the executing process with respect to specific monitoring goals; such as measuring performance indicators for tracking process's artifacts to ensure that the process meets expectations (Meroni, 2019).

As a process model serves as an input to enact a process by a PMS, the PMS's effectiveness on managing the operational process relies on the quality of the process model (Reijers, 2021). Process models can have different granularity depending on the needs that must be satisfied at operational level. Therefore, for a successful process management implementation project, it is crucial to create process models containing necessary details designed to meet certain process monitoring goals.

Traditional activity-centric process modeling mainly focuses on the workflow of process tasks and gives a little importance to data resulted by process execution. As a consequence, there is often a gap between process tasks and business operations on data that leads to a separation between PMS and applications used for business operations. We adopt the emerging paradigm Artifact-Centric Processes Modeling (ACPM) that describes process based on operations on data, thus offers a more integrated manner to take into account both data and process perspectives (Cohn and Hull, 2009). Furthermore, in recent times, synergies between IoT, Big Data and data-driven process monitoring have taken place(Kun et al., 2015), giving artifact-centric more preeminent.

The research literature shows considerable attention to developing artifact-centric process modeling languages. However, few studies have investigated the methodology to systematically model processes based on the artifact-centric approach. Consequently, modeling a process based on artifact-centric approach stays quite challenging (Kun et al., 2015; Wan and Liu, 2014), especially to elaborate a useful process model for a specific monitoring goal.

To adresse this lack, we propose *ArtProcsMod*(Artifact Process Modeling), a goal-oriented modeling methodology to assist modelers in creating an artifact-centric process model that satisfies a specified process monitoring goal. The rest of the

Abualsaud, R., Tran, H., Ober, I. and Nguyen, M.
Toward a Goal-Oriented Methodology for Artifact-Centric Process Modeling.
DOI: 10.5220/0011989900003464
In *Proceedings of the 18th International Conference on Evaluation of Novel Approaches to Software Engineering (ENASE 2023)*, pages 656-663
ISBN: 978-989-758-647-7; ISSN: 2184-4895
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paper is structured as follows: Section 2 introduces the artifact-centric process modeling approach; Section 3 describes the *ArtProcsMod* methodology and illustrates it in a running example. Section 4 discusses the related work. Section 5 concludes the paper and outlines future works.

2 ARTIFACT-CENTRIC PROCESS MODELING

The common ground for artifact-centric process modeling can be described by the BALSA framework (Hull, 2008). We outline here the four dimensions of the framework:

- **Business Artifact** represents a key business-relevant object used in the process. Each artifact is characterized by data attributes.
- **Life-cycle** expresses the evolution of an artifact, from its creation until its termination.
- **Service or Task** is an action manipulating an artifact and making it evolve.
- **Association** associates a Task with an artifact to represent the impact of the task on the evolution of the artifact.

There are different works proposing concrete languages to represent the BALSA's elements. Inspiring by the works of (Künzle and Reichert, 2011), we represent an artifact-centric process model of *ArtProcsMod* methodology at two levels:

1. **Macro Process Model:** represents the process's artifacts and the relationships between them.
2. **Set of Micro Process Model(s):** For each artifact, a corresponding *micro process model*is created to describe the artifact. Such that, a micro process model consists of an information model and a life-cycle model:
   (A) The *information model* specifies the attributes relevant to describe the artifact and its relationships to other artifacts.
   (B) The*life-cycle model* specifies the behavior of an artifact, i.e. the possible ways that an artifact might progress through the business. In this paper, the life-cycle represents by a finite state-machine. Tasks are associated to transitions to express manipulations on the artifact that make it change states. Each state represents the evolution of the artifact after the task associated with the state's incoming transition is done. To reflect a finer evolution of an artifact, a state can be decomposed into a set of sub-states representing the effects on manipulating a part of the artifact, e.g. an attribute. Each task is associated with one role responsible for performing the task.

Figure 1 illustrates the intended *macro process model* and *micro process models* with the key components.

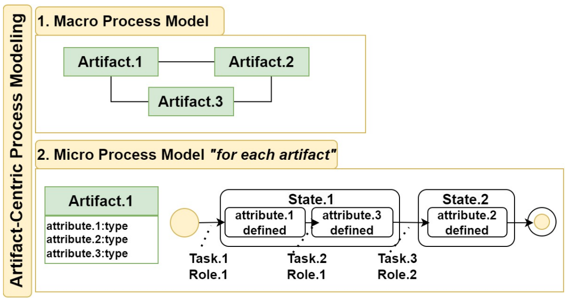

Figure 1: Artifact-Centric Process Model.

In this paper, we refer to the artifacts described in a process model as "observable artifacts". I.e. an artifact represents an item that a participant needs to observe during the enactment of the process.

3 ArtProcsMod MODELING METHODOLOGY

3.1 Motivating Example

This section briefly presents a motivating example and points out the difficulties of modeling the process using artifact-centric approach. In this example, we model a software process based on the Rational Unified Process®(Kruchten, 2004) (RUP). Due to the limit of space, we only examine the partial RUP-based process to define system requirements and test plan for development iterations as depicted in Figure 2.

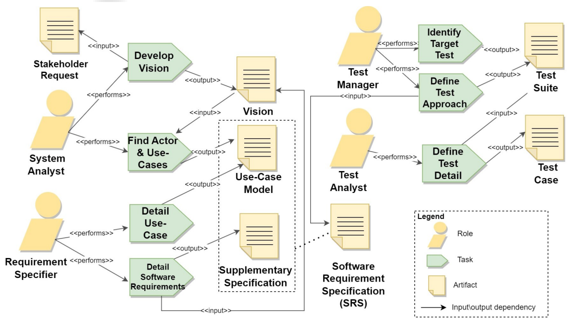

Figure 2: RUP Requirement and Test Defining Process.

The monitoring goal of the process's participants is supporting the traceability of working artifacts during process execution. This goal is refined in a set of process monitoring needs (c.f. Table 1) on the traceability to gain further insights on the process execution.

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Traceability means the ability to trace work items across the development life-cycle. To do so, the traceability model describes trace links between trace items (Cleland-Huang et al., 2012). Artifact-Centric Process Model could play the role of a traceability model, where the observable artifacts are trace items and the relations between artifacts are trace links. The challenge here is how to provide accurate trace links to fulfill the traceability needs. In other words, the modeling difficulty is identifying the artifacts and inter-artifacts relations that should be included in the process model to enable an effective traceability.

3.2 Methodology Overview

ArtProcsMod can be characterized as being, in the main, concerned with the modeling of a process based on its monitoring goal. Making process monitoring needs explicit, the designed methodology aims to provide a useful process model substantiating the process monitoring ultimate goal.

The methodology, depicted in Figure 3, consists of five steps which are split into two phases. We assume that the process monitoring needs are determined and provided as input along with the process description. The methodology's steps measure the fulfillment of performance obligation i.e. delivering an ACPM centered on the process monitoring needs. The intended delivery outputs from this methodology are a *macro process model* and a set of *micro process models*. For each step, we describe the purpose, the inputs, the outputs and the guidelines (i.e. modeling best practices). In addition, we demonstrate each step by applying it in a running example.

3.2.1 Pre-Modeling Phase

The aim of pre-modeling phase is to have a clear understanding of the process and the process monitoring needs, in order to propose a set of *process modeling requirements* that will be used as a base to direct modelers during the modeling phase.

Step 1: Analyze Artifact Relations

Objective**:** to provide a holistic view of the managed artifacts, their relations and characteristics.
Input**:** *process description*, which can be gathered either through interviews or documentation.
Output**:***initial macro process model* showing the process's participating artifacts and their relationships.
Guidelines**:** in this step, the modeler needs to analyze the process description in order to identify the artifacts participating in the process and the relations between them. The complexity of this step depends on the level of formality of the *process description*.
Application in the Running Example**:** from the RUP process description in Figure 2, we identify the participating artifacts corresponding to the "trace artifacts" of RUP. By analyzing the inputs and outputs of RUP activities, we can deduce the dependencies between the artifacts as shown in Figure 4.

Step 2: Specify Modeling Requirements

Objective**:** to develop a set of process modeling requirements from a given process monitoring needs.
Input**:** *Process Monitoring Needs* (PMN), which are statements specifying in-details the process monitoring goal. Each need expresses the information that the process participants want to know when executing the process. In general, such information concerns the process items that must be traced at run-time. Those items are in fact the instances of some observable artifacts in the process model. An extraction of the PMN for the running example is given in Table 1. They specify the concrete needs of traceability as the monitoring goal.

Table 1: Process Monitoring Need (PMN).

PMN1	Identify the impacted Use-Cases (UC) when changing the concern of a particular Stakeholder Need (SKN).
PMN2	Identify the impacted UCs when changing the content of the Iteration Test Package.
PMN3	Identify the Users who are responsible for manipulating a particular UC.

Output**:** *Process Modeling Requirements* (PMR), which are statements that are requisite to confirm the process monitoring needs. The idea of stating the process model requirements is to ensure the specification of the observable artifacts and/or relations that we need to have in the process model.***Guidelines*****:** for each monitoring need:

a. Identify the required observable artifacts.
b. Identify the required observable relations.
c. Identify the set of required observable tasks that entails the set of actions required to manipulate a specific artifact.

The challenge of this step is to make an abstraction from the needs expressed on instance level into the requirements on the process elements on the model level. To facilitate this model requirement elicitation step, we collected and analyzed various PMN and their corresponding PMR to identify the common transformation rules. As a result of this work, we propose some transformation patterns to transform a need PMN to a requirement PMR.

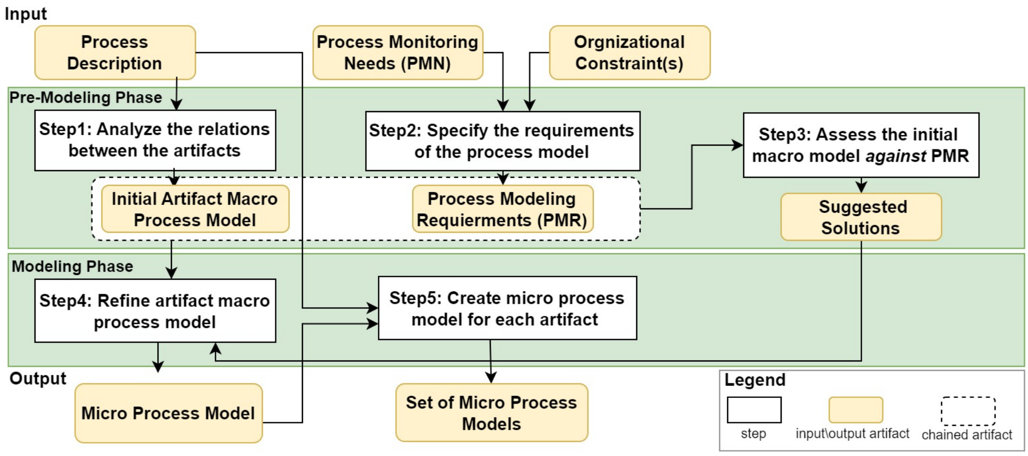

Figure 3: Schematic overview of *ArtProcsMod* Methodology.

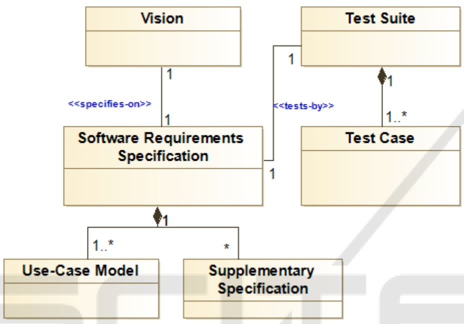

Figure 4: Initial macro process model.

Table 2 illustrates one transformation pattern that can be applied to the needs **PMN1** and **PNM2** in Table 1. An in-depth discussion of the full list of patterns are omitted to conserve space.

Table 2: PMN2PMR Transformation Pattern.

PMN	Identify the impacted Artifacts **A2** when changing Artifacts **A1** by doing Action **S**
PMR1	**A1** must be an observable artifact
PMR2	**A2** must be an observable artifact
PMR3	The relation between **A1** and **A2** must be observable
PMR4	The action **S** must be observable

***Application in the Running Example*:** Table 3 depicts the requirements developed from the need **PMN1** in Table 1, by applying the pattern in Table 2.

Step 3: Assess the Initial Macro Process Model Against the PMR

***Objective*:** to verify if the initial macro process model satisfies the PMR identified in the previous step.
***Input*:** PMR and *initial macro process model*.
***Output*:** list of *suggested solutions*, which propose the modeling solutions for unachievable requirements.

Table 3: PMRs developed from PMN1 and PMN2.

PMN	**Process Modeling Requirement (PMR)**
PMN1	**PMR1**: SKN must be an observable artifact. **PMR2**: UC must be an observable artifact. **PMR3**: The relation between SKN and Use-Cases. must be observable. **PMR4**: The actions of changing the concerns of a SKN must be observable.
PMN2	**PMR5**: Use-Case must be an observable artifact. **PMR6**: The Iteration Test Package must be an observable artifact. **PMR7**: The relation between Use-Case and the Iteration Test Package must be observable **PMR8**: The actions of changing the content of an Iteration Test Package must be observable.

***Guidelines*:** for each PMR

a. Identify the required improvements and/or lack relative to the *initial macro process model*. The lack might be a missing artifact(s) or relation(s) in the *initial macro process model*.

b. Analyze the cause of the lack. The lack includes a missing artifact in the *initial macro process model* and/or missing relation. Accordingly, the most common causes include: the missing artifact is a composite attribute specified in another artifact or the missing artifact does not described in the *process description*.

c. Suggest solution to the defined lack. The *suggested solution* proposes a solution to enrich the *initial macro process model* to ensure that the process model encompasses the details necessary to achieve the corresponding PMN. The solution will be used as a base for the modeling phase.

Once more, to facilitate the generation of solutions for recurrent problems, we analyzed common causes of lacks and proposed some modeling patterns for such problems. Table 4 shows two of these modeling pat-

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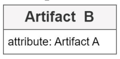
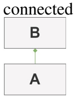
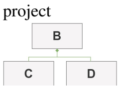
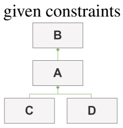
terns to handle the problem of a missing artifact A. According to the PMR, A must be observable but it cannot be found in the current *macro process model*. There are two possible causes of such a problem as shown in Table 4. For each cause, the pattern suggests a solution.

Table 4: Solution Patterns for Missing Artifact Problem.

Lack	Cause	Suggested Solution
Artifact A is missing	A is a "hidden" component of a composite artifact B 	Represent A as an artifact connected to B 
	A is not explicitly described in the standard process description, but in some specific constraints of the project 	Define a new artifact A and create the relation from A to related artifacts based on the given constraints 

Application in the Running Example. Table 5 illustrates the results of the assessment of the *initial macro process* (c.f. Figure 4) against the requirements related to the PMN1 and PMN2. We only show some requirements concerning the *macro process model*, concretely the PMR1, PMR2, PMR3 and PRM5 and PMR6.

Consider the PMR1 "SKN must be an observable artifact". From the *initial macro process model*, a SKN is a missing artifact because it is "hidden" in the artifact Vision as a component. Thus, we suggest a refinement of the artifact Vision to model its components as observable artifacts as well. Thus, SKN becomes an observable artifact as required in PMR1.

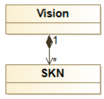
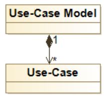
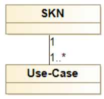
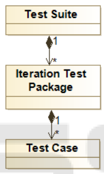
Another example considers the PMR3 "The relation between SKN and Use-Cases. must be observable". From the *initial macro process model*, the relation between SKN and UC is missing because these two artifacts are not observable. However, there exists an indirect dependency between these two artifacts through their parents, i.e. the relation between Vision and Software Requirement Specification(SRS). In order to facilitate traceability of changes impacts on UC when changing SKN, a direct relation should be established between these two artifacts.

3.2.2 Modeling Phase

Step 4: Refine Macro Process Model

Objective*:** to refine *the initial macro process model* by taking into consideration the*suggested solutions* proposed in Step 3.Input*:** suggested solutions and the initial macro process model. The

Table 5: Suggested Solution.

PMR	Lack & Cause	Suggested Solution
PMR1	SKN is missing *SKN is a hidden component of the artifact Vision*	Represent SKN as an artifact connected to Vision. 
PMR2	UC is missing *UC is a hidden component of the artifact Use-Case Model*	Represent UC as an artifact connected to Use-Case 
PMR3	Relation between UC and SKN is missing *The artifacts in this relation are missing in the initial model*	Make an observable relation between UC and SKN 
PMR5	c.f. PMR2	c.f. PMR2
PMR6	Iteration Test Package is missing *The Iteration Test package is not a standard RUP artifact but an local organizational artifact*	Define Iteration Test Package artifact which contains the Test-Case planned for an iteration 

suggested solutions indicate which observable artifacts and relations should be added to the *initial macro process model*.***Output***: Final Macro Process Model.***Guidelines*:** In this step, we need to consider the suggested solutions from Step 3 and refine the *initial macro process model* accordingly.***Application in the Running Example*:** Figure 5 shows the *macro process model* as the result of this modeling step on the running example.

Step 5: Create Micro Process Models

***Objective*:** to create a micro process model for each artifact defined in the macro process model in Step 4. ***Input*:** the final macro process model *m*, the suggest solutions *s* and the process description *p*. The *macro process model* defines the set of artifacts that *micro process models* must be created for. The *Suggested solutions* indicate the required actions that must be observable in the micro process life-cycle model. The business rules, (provided in the *process description*), give details on the tasks corresponding to the actions manipulating a specific artifact. Generally, business rules specify the role performing an action, the precondition to enable the action and the post-condition to describe the effect of the action on

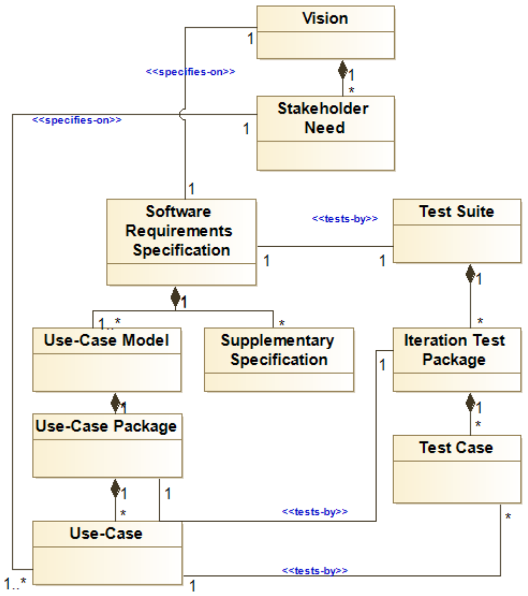


Figure 5: Final Macro Process Model.

an artifact. ***Output*:** a set of micro process models. Such that, for each artifact defined in the *macro process model*, a corresponding micro process model is created. A *micro process model* consists of two models. Namely, information model and life-cycle process model.***Guidelines*:** for each artifact $a \in m$:
*1. Create the Information Model of **a***: describing *a*'s attributes extracted from the given process description.
*2. Create the Life cycle Model of **a***: defining a behavioral model for an artifact is not a trivial task. We propose some guidelines to progressively create the life cycle model of an artifact.
2.1. Create an initial life-cycle model
In this step, we create an initial life-cycle from the *process description*. We suggest the following Modeling Rules (MR) to realize the step:

a. **MR.1.** For each artifact's attribute *att* of the artifact *a*, define a corresponding state $attDefined$ corresponding to the data acquisition of the attribute *att*.

b. **MR.2.** For the attributes that are manipulated by one named task specified in one of the business rules, group their corresponding states into a composite state. To do so, from the *process description*, identify the business rules that must be satisfied by the artifact *a*. From those business rules we can infer if some attributes can be manipulated simultaneously, accordingly they can be enclosed by one state.

c. **MR.3.** Establish the transition between the states. From the *process description*, identify the business rules that must be satisfied by the artifact *a*. From the pre and post conditions of those rules, infer the transitions between the states of *a*.

Some rules are not easy to translate in a straightforward way. Thus, in order to streamline the work for modelers, we provide some patterns to generate the life-cycle's states from the business rules. One transformation pattern is shown in Figure 6 illustrates how the preconditions and post-conditions of a task specified by the business rule are transferred into states in the life-cycle model with the task is the transition between these states.

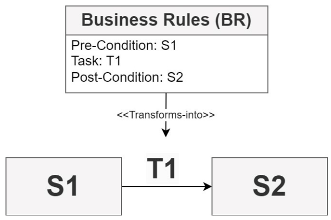


Figure 6: Business rule to life-cycle transformation.

2.2. Assess the initial life-cycle model against the process modeling requirements
In this step, we refine the initial life-cycle based on the *suggestion solutions* obtained from Step 3 in order to ensure that PMRs are satisfied. The assessment includes defining the lacks (e.g. required observable actions) from the PMR Step 2 and refine the life-cycle accordingly.
Application of the step in the running example: We develop a *micro process model* for the artifact Stakeholder Need (SKN).

First, we create the SKN information model by identifying its attributes. Second, we create the SKN life-cycle model following the guidelines. Figure 8 illustrates the SKN micro process model. As illustrated in the Figure 8 (A) implies defining the states of SKN by applying the MR.1, which states that for each attribute a corresponding state is created. Figure 8 (B) represents the SKN initial life-cycle after grouping attributes that can be manipulated simultaneously into one state by applying the MR.2. Figure 8 (C) represents the refined life-cycle (i.e. satisfies the PMR4 for the PMN1, which states "The actions of changing the concern of a SKN must be observable". From this requirement we can infer the need of tracing the SKN state when its related concerns are changed, and accordingly, we translate this by creating a corresponding observable state.

The running example shows that the steps in *ArtProcsMod* confer benefits to create viable Artifact-centric Models that are aligned with the *process monitoring needs*.

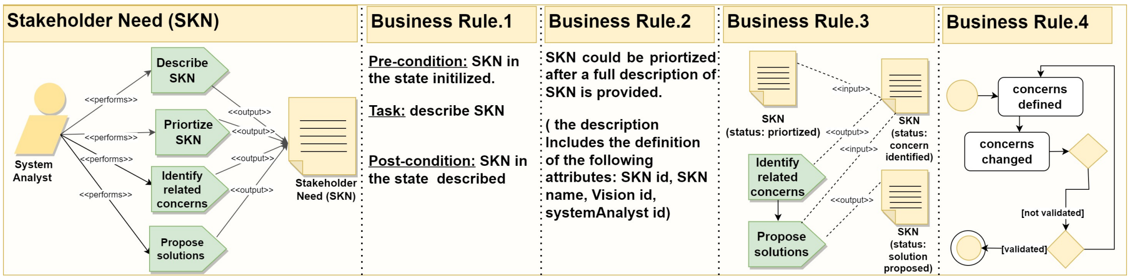


Figure 7: SKN - related tasks and business rules (extracted from the process description document).

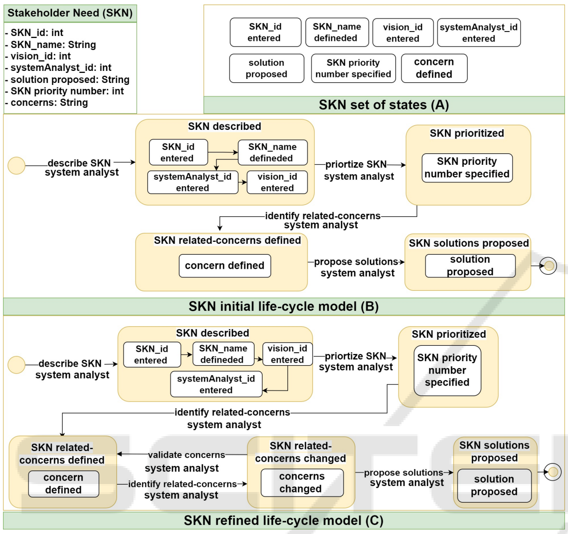


Figure 8: Stakeholder Need micro process model creation steps.

4 RELATED WORKS

In this section, we examine the related work in two areas: first, the works on representing processes from the artifact-centric perspective; second, the works proposing methodology to create artifact-centric process models. Artifact-Centric Process Modeling (ACPM), first introduced in (Nigam and Caswell, 2003), with a view to focuses on the data that is needed to carry out the different tasks in a process, and the dependencies between these data.(Hull, 2008) presents the BALSA framework in order to facilitate the definition and the structuring of ACPM. In 2010, a declarative style of ACPM, called Guard-Stage-Milestone (GSM), was introduced(Hull et al., 2011). Other approaches related to ACPM introduced by (Van der Aalst et al., 2017), who provides an object-centric behavioral constraint approach combines ideas from declarative, constraint-based languages, and from data modeling techniques. A continuous research on developing a flexible framework for an object-aware process management system is realizing by PHILharmonic Flows group(Künzle and Reichert, 2011).

Concerning the methodologies to model processes based on ACPM, there are some works such as (Fritz et al., 2009; Eshuis and Gorp, 2015; Popova and Dumas, 2013; Kumaran et al., 2008; Governatori and Rotolo, 2010) study the formal aspect to enable deriving an artifact-centric specification from a process-centric one or vice-versa. However, small number of studies investigate a methodology to systematically model processes based on ACPM. To our knowledge, there is only (Bhattacharya et al., 2009) that proposes a data-centric design methodology to define different life-cycles for different artifacts from scratch. And (Yongchareon and Liu, 2010) that develops a bottom-up abstraction mechanism to derive views from underlying process models according to view requirements. The works in (Bhattacharya et al., 2009) and (Yongchareon and Liu, 2010), however, do not provide concrete guidelines for modelers to define process based on ACPM.

5 CONCLUSIONS

This paper presents *ArtProcsMod*, a goal-oriented modeling methodology to create an Artifact-Centric Process Model (ACPM) that satisfies a specified process monitoring goal. The study reveals several challenges when modeling the process to support a specific monitoring goal in the running time, such as defining the right level of granularity of an artifact or the need of defining intermediate artifacts. We propose solutions to address these challenges as part of our iterative application of *ArtProcsMod* in modeling a portion of the Rational Unified Process (RUP) with the intention of enhancing traceability at execution time.

From the present study, we observe that the artifact-centric process model can play the role of the Traceability Information Model(TIM)(Cleland-Huang et al., 2012), detailing the artifacts and the relation between them. A particular strength of an ACPM created with *ArtProcsMod* with enhancing the traceability is that it derived from designated process monitoring needs. The application of the process monitoring needs allow ACPM to specify intermediate artifacts that lead to enhance the accuracy of the trace path. In addition, ACPM supports the integration of *roles* in the informational model. Hence, allowing the creation of trace paths between the roles and the produced or manipulated artifacts. And finally, ACPM keeps track of the tasks that are meant to produce an artifact.

As part of our future work, we plan to further evaluate the methodology by applying it in real-life cases where traceability is important, e.g. software development and healthcare system. Another direction includes discovering more modeling patterns for some determined methodology's steps. More thoroughly, we intend to propose a process modeling language, that directly specifies process modeling requirements and enables automatic transformations of some *ArtProcsMod*'s steps.

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