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ArSPI: An Artifact Model for Software Process Improvement and Management

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Abstract

Software process adaptation and improvement (SPI) addresses the need of companies to adapt new and/or improve their software processes in order to meet, e.g. business optimization goals or regulative requirements. Such an initiative comprises manifold activities, e.g. analyzing, designing, realizing, evaluating, and deploying new software processes or, respectively, new versions/variants of a maintained software process. Therefore, such initiatives are often considered to be (self-contained) projects.

Although reference models such as CMMI and ISO 15504 contain practices and assessment methods they, however, lack in defining supporting artifacts for SPI projects, which help process engineers to structure the outcomes, to guide process engineers during the set-up and the operation of SPI projects. Therefore, setting-up and operating SPI projects highly depends on the individual expertise of process engineers. In this report, we present a compact artifact model and a set of complementing processes to support SPI projects and software process management (SPM), which we inferred from six years of experience. The presented model serves as template for creating analysis, design, and supporting artifacts in SPI projects. Furthermore, the artifact model is embedded into an organizational context in which SPI projects are initiated and executed, and the results are deployed to the process consumers.

The report at hands serves as "data sink" and contains all detailed artifact model descriptions and further information aiding the definition of a software process management approach and, furthermore, provides guidance to process engineers to organize and manage a particular SPI project.

Keywords

Software Process Improvement, Software Process Management, SPI, Artifact Model

CR-Classification

D.2, D.2.9

Reviewers

The report at hands is the result of numerous discussions. It was reviewed and discussed with the following people (in alphabetical order):

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1 Introduction

Although being a topic of interest for many years, software process improvement (SPI) and software process management (SPM) remain challenging tasks, e.g. [14], [19], [28]. Software processes are the glue that holds organizations, projects, and people together. Depending on the context, software processes may comprehend up to thousands of process elements, which need to be designed, implemented, quality assured, and managed. In contrast to lightweight agile methods, comprehensive software processes – as for example used by "global players" – thus have high requirements, e.g. on process engineering frameworks. Therefore, the development, the maintenance, and the improvement of a software process constitute challenging tasks for – at least – two reasons: (1) organizational reasons that comprehend methodical and technical aspects, and (2) psychological reasons. Especially in the area of technical and methodical support for process engineers, our research results show several gaps, e.g. regarding the maturity of process engineering frameworks in general, or process construction and management methods in particular (cf. Sect. 2).

Besides the research results, our day-to-day business in consulting and executing SPI projects also shows a gap in the methodical support. Process engineers often have to use a "trial & error" approach; a concrete playbook that summarizes the essential tasks and the minimal set of artifacts (including the required structure and contents) is not defined by the established standards at all (cf. Sect. 2). To this end, process engineers have to develop their own "best of breed" approaches in order to master SPI projects. The difficulty increases if not only a single SPI project is considered, but a comprehensive software process that is part of a (evolving) software process line (SPL; e.g. [41], [82], [86]). All results that are produced in a SPI project, e.g. process designs, process releases, have to be considered from a different perspective.

In this section…
In this section, we first describe the background of our research in Sect. 1.1. We describe the projects in which we developed and tested our approach. At the end of this section, we present the overall contribution of the report at hands, outline the research methods, and give an outline of the whole report document. For readers, who are not interested in the "preludes" the out come of our research – the artifact model for SPI and SPM – is briefly described in Sect. 4, and described in every detail in Sect. 7 et seq.

1.1 Context and Project Settings

Our work is based on a number of SPI projects, which we operated over the years. The majority of these projects were done in the context of the German V-Modell XT[1] and, therefore, also the V-Modell XT inspired the presented results. In this section, we give a short overview over these projects and provide some context information[2].

The information of the projects to which we refer is summarized in Table 1. The column "Domain" classifies the project. The classifier "Gov" points to a project, which was operated in the context of a government agency, whereby the postfix "G" indicates a project, which deals with general administration tasks, e.g. procurement, bidding, acquisition, contracting, service provider management, project monitoring, or administration in general. The postfix "SD" indicates processes that address software development. While the "G" variants still stay on a fairly generic level, the "SD" variants contain concrete artifacts and methods aiding software development teams in software projects. The classifier "Industry" indicates a process that was deployed in a company dealing with software development. In the column "#PE", we classify the number of process engineers[3] participating in the SPI project. In the same way, we give the numbers for the duration (in years) and the effort (in person

[1] For detailed information regarding the V-Modell XT, please refer to http://www.v-modell-xt.de (an English version is available). The V-Modell XT is a *process-engineering framework* in which tools, metamodels, and reference implementations build a comprehensive infrastructure to define (software) process models. A short introduction can be found in [85] and [86], in-depth introductions and further information can be depicted from, e.g. [21] (reference process model), [87] (process metamodel), and [59] (technical customization method).

[2] For confidentiality reasons, we cannot give detailed information to all of the considered projects. Most of the projects were operated in a government environment and, therefore, underlay strict non-disclosure agreements.

[3] For confidentiality reason we cannot give the exact numbers, but provide an interval classification.

months; *pm*). Only for the project *5-Witt* we can give exact numbers, as the project and its outcomes are already published [4], [12]. The following columns "Content", "Tools", "Metamodel", and "Status" summarize the following information:

- Content: *What was/is the objective of the project?*
  - "P" → a (stand-alone) process model
  - "PR" → a reference process model, which serves as basis for further variants
  - "PV" → a process variant, which is based on a reference process model
- Tools: *What kind of tools was developed in this project?*
  - "E" → editors or authoring tools
  - "A" → assistance tools, e.g. supporting tools for tailoring the process
  - "I" → infrastructure, e.g. build tools, build servers
  - "N" → no tools at all
- Metamodel[4]: *Were there metamodel changes, extensions, or improvements?* "Y" – Yes, "N" – No.
- Status: *What is the status of the project or the resulting processes/process variants, respectively?*
  - "D" → development: the process is still under (initial) development
  - "M" → maintenance: the process is in use and is now maintained
  - "N" → the process is in use, however, further information are under NDA
  - "U" → unknown: the current state is unknown, e.g. because of company reorganization
  - "O" → open source (tool project only): tools are published as open source projects

Remarkable, in the project "1-RM"[5], which runs since 2004, more than 35 people were working over the years. However, the actual core development team that is responsible for maintenance and further development and improvement consists of about 7-10 people.

Similar to the number of involved process engineers, we categorize the projects' duration using interval classification. It has to be mentioned that the given numbers relate to the initial SPI projects in which the initial customizations were done. Especially the projects *1-RM*, *2*, and *4* are already deployed and subject to maintenance and further improvement, which causes additional continuous effort.

The last project of the table aimed at investigating the possibilities of providing seamless process-tool integration. Given a machine-readable process model particular tool-based project environments can be derived from the process structure and description. Although not being a "classical" SPI project, CollabXT provided a different perspective on the design and the development of a software process. Furthermore, outcomes form this project also influenced further SPI project, e.g. by providing richer tool support and by bridging the gap between the process engineers and the process consumers.

Table 1 Overview over the projects.

Project	Domain	#PE	Duration (in years)	Effort (in *pm*)	Content	Tools	Metamodel	Status	Further information
1 - RM	Gov/G	>5	> 5	> 200	PR	E A I	Y	M	• More than 10 partners for development, use, evaluation • Related contributions: e.g. [79], [57], [58], [21], [59], [41], [86] • Several releases, cf. [85]

[4] The V-Modell XT is a fully metamodel-based process (similar to the EPF- or SPEM-based software processes; cf. [85] or [56]). Since the metamodel is the "process language" in which the process model is strucutured and described, metamodel customizations can occur if certain requirements deman new or extended language features.

[5] In this project, the core of the V-Modell XT software process line – the so-called "reference model" – is developed and, nowadays, maintained.

Project	Domain	#PE	Duration (in years)	Effort (in *pm*)	Content	Tools	Metamodel	Status	Further information
2	Gov/G	>5	2 - 4	15 - 25	PV	E A	Y	N	• 3 parties for the development, several government agencies for the evaluation
3	Gov/SD	2 - 4	1	10 - 15	PV	I	Y	N	• Mature and experienced organization • Extension of a rich directed process model with a particular software development approach paying special attention customer/constructor interfaces and iterative (agile) software development
4	Gov/SD	2 - 4	2 - 4	10 - 15	PV	E A	N	N	• Mature and experienced organization, however, final customization incl. deployment was achieved in the 3rd approach (reasons: strong opponents, technical evolution during the SPI project)
5 - Witt	Industry /SD	2 - 4	2	SPI: 20 Witt: 600	P	N	N	U	• Development of a process, which uses the reference model and its infrastructure; purpose: software development • 4 partners incl. the executing company • Related contributions: [4], [12] • Current status: unknown (company reorganization)
6	Gov/G	1	1	5 - 9	P	N	N	D	• Development of a process, which uses the reference model and its infrastructure; purpose: general administration and project management of method and software development projects • Current status: ongoing, initial release deployed for evaluation
7 - CollabXT	Tool	2 - 4	1	<5	-	A	-	O	• Tool development project to enable transformation of processes in order to be executed by several project-supporting tools • 3 partners • Related contributions: e.g. [42], [46], [47], [48], [50]
8	Gov/SD	2-4	1	5 - 9	PV	N	N	U	• Development of new sub process dealing with data model development. • Current status: project was stopped for organizational issues of the client (re-prioritization); project was re-opened 2 years later; current state: unknown

All projects from Table 1 (except CollabXT) resulted in software processes or software process lines of considerable size. A couple of thousands of process assets (for the terminology, see Sect. 4.1.2) had to be designed, realized, and maintained over the years.

To provide some (technical) insights, Table 2 shows the numbers of the process assets of 4 selected software process variants. The variants refer to the projects from Table 1 in which they were initially developed. Also, variant *2* is a child of the reference model (*1-RM*), the variants *3* and *4* are children of variant *2*. In consequence, the processes mentioned in Table 2 create a variant tree or – more intuitive – a *family tree*. The whole V-Modell XT family is analyzed in our technical report [85]. To underline the importance of a structured and efficient approach to manage such large-scale software processes/software process lines, Figure 1 shows the family tree and the relationships between the single variants and their respective evolution over the years.

Table 2 Size and complexity of the V-Modell XT variants under consideration.

Criteria	Selected V-Modell XT Variants				Counted process model elements
	1-RM (1.3)	2	3	4	
Referable model elements	4002	3507	3902	2889	All elements with an id (referable by other process elements)
Documentation elements	915	758	855	657	e.g., work products, roles, activities
Configuration (container)	43	34	36	24	e.g., project types, project characteristics
Procedural elements	292	278	300	165	e.g., procedure modules
Configuration (process content)	1637	1324	1469	1140	e.g., relationships, dependencies
Process documentation	842	498	551	480	Number of generated pages of the process documentation in PDF format

To show the spectrum and the variety of improvements and development tasks, even the selected processes and process variants provide valuable insights.

Besides the customization of the process structure and content, and the complementing tools, even the metamodel was extended in some projects. Due to the customer requirements, in project *2* a considerable extension of the metamodel was necessary (the majority of the extensions addressed the set of operations used to create a variant in the process line; cf. [86]). Furthermore, also in project *3* some extensions to the already extended metamodel from project *2* were requested and implemented. The evolution of the metamodel is a critical task as it – on the one hand – extends the options of the process engineers, but – on the other hand – also requires tool development tasks and further activities, e.g. the re-configuration of export templates. In the worst case – which we also could observe – extensions and customizations can raise compatibility issues, which can only be managed by establishing a strict configuration management. Another important aspect is the conformance of a process variant to the reference model, which might be affected by newly introduced operations (more on this topic in Sect. 3, 7.1.3, and 8.4).

Remark
Besides the aforementioned “complete” SPI projects, we were also involved a number of further, smaller SPI activities. For instance, in the context of the “Federal Foreign Office” we were involved in the development of user guidance that substantially extended the existing guidance provided by the deployed agency’s standard process. Another example: In the context of the “Federal Office of Administration”, we were involved in a SPI project (project *8* from Table 1) that aimed at including procedures to develop standardized data formats into the overall standard development process model.
While the small guidance was successfully deployed, the SPI project on data format development was stopped due to a reprioritization of the agency’s overall project portfolio. *Important in this context is:* Two years after the stop, the project was reopened but with a different process engineering team. The new team could directly start since all analyses and designs as well as first prototypical implementations were completely documented.

The Special Situation in Government Agencies. As shown before, most of the considered projects are in the context of government agencies and, therefore, face specific requirements and settings. In [53], we provided first insights into this domain. However, we want to provide more information in the following to mention the particular circumstances that, inter alia, explain the model that we present in this report.

Government agencies are strictly hierarchical organized. When it comes to a SPI project, a number of organization units have to be included, e.g. human resources, legal affairs, procurement, IT-operations, and so forth. Furthermore, government agencies are usually evolved structures operating a number of large-scale and mature business processes. To this end, newly developed or updated/improved processes have to pay attention to the host environment. One important aspect that needs to be considered is that due to the organizations’ nature changes, especially changes regarding the processes need time for their dissemination. For instance, the investigation from [53] was conducted 5 years after the initial process deployment to get enough projects finished for data collection and experience extraction. Regarding the software development process, government agencies are also in a special situation. On the one hand, these agencies run projects ranging from small few-person-day activities to complex multi-year and multi-billion Euro projects [53], which requires highly flexible processes

that adequately address small projects as well as large projects. On the other hand, government agencies often have only partial, if at all, long-term strategies or roadmaps; a considerable share of their projects is motivated by parliamentary decisions, e.g. a new law that (a) requires a supporting software system and (b) dictates deadlines. Summarized, government agencies as rather static institutions then again face the requirement to act very flexible and agile when it comes to a software development project.

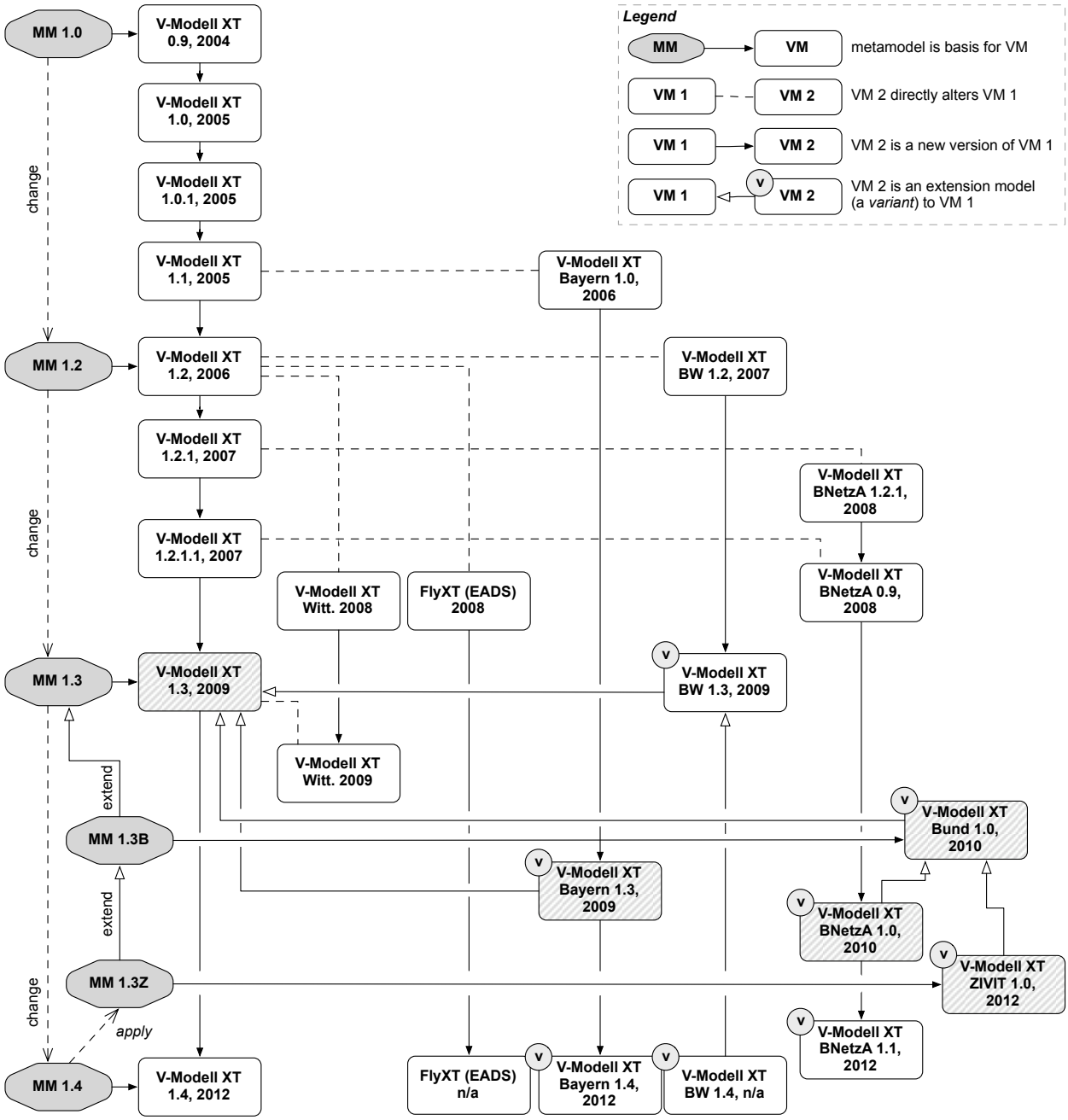

Figure 1 The V-Modell XT family tree (analysis from January 2013)

SPI projects in such a context need to pay attention to this special situation and, therefore, have to mention the evolved structures, interfaces to other organization units, and a number of regulations to create software processes that address the administrative requirements as well as the ones related to software development.

The Process Engineering Teams. The majority of the considered projects from Table 1 was executed by a process engineering team, which integrated the process engineers as well as the client-side process owners and also process consumers. Due to the interdisciplinary nature of the SPI projects, the teams consisted of develop-

ers of the process platform, requirements management and project management experts, process management experts and process owners, and supporting personnel. Each team member had a special area of responsibility, e.g. process analysis, process architecture, process implementation, or platform development. For the comprehensive SPI projects *1-5*, the specialization was a necessity, as certain tasks need to be done and aligned to create a complete process release.

Remark
Notably, similar to a software development project a SPI project bears risks; and *communication issues* in the process engineering team cause most of them. For example, in one of the projects, the lead process engineer temporarily left the team whereby a handover was not completed. In consequence, some former decisions were not reproducible anymore and actually agreed work packages were re-opened. Summarized, a SPI project requires a competent process engineering team. If a single process engineer drives a SPI project, inner-team communication is not that important, however, the entire communication to the stakeholders has to be ensured, and *no required task in the SPI project should be left out*. Single process engineers as well as a whole team therefore need a *playbook* to succeed in a SPI project.

1.2 Contribution

Over the years, we were involved in a number of SPI projects ranging from smaller, evolutionary projects aiming at improving selected methods to large-scale SPL-based software processes. We often experienced the lack of concrete guidance and support. To this end, we had to – on the one hand – to extract relevant information from the current scientific literature, practitioner's experiences and standards, and – on the other hand – learn from our experiences. Over the years, we developed and refined different techniques and approaches that – stepwise – provided us the required support.

In the report at hands, we summarize our experiences and present a generalized, technology-independent model that contains artifacts and complementing processes necessary to organize and manage SPI projects. Furthermore, we show the hot spots on which the interfaces to the host organization are defined in order to lay the foundation for an organization-wide software process management (SPM). The presented model lays the foundation for further research, especially to extend standard assessment and maturity models such as CMMI by an experience-based and proven artifact model that describes standardized outcomes of SPI projects.

1.3 Research Method, Previous Investigations, and Related Contributions.

The model that we present in the following is based on our experiences that also resulted in some contributions. In this section, we briefly describe the research methods applied, and we list the previously published material.

Regarding the reference model (Table 1), we conducted a field study [53] to investigate the feasibility of the reference model. The outcomes were, inter alia, used to aid the development of a V-Modell XT variant specific for the public administration. In this particular endeavor, information and lessons learned from an industrial project were also included [4], [12]. Furthermore, smaller projects that aimed at tool development, e.g. [46], [50], also contributed to a first V-Modell-XT-specific development and improvement method [27], [45], [44], and [59], which was inspired by process line development, e.g. [41], [82] and [86], but described on a fairly technical level. Over the years, we refined and generalized the proposed method, and applied it in the projects *3, 4* and *8* from Table 1. Already during this particular application, we refined the generalized approach and tested the improvements with student groups [54], [55]. As the outcomes proved appropriate we tailored and applied the approach again in project *6* from Table 1. In order to get sound results, we applied the following research methods (brief overview):

Table 3 Overview over the applied research methods.

Method	Description
Surveys and interviews	In order to get project experiences and concrete requirements to be mentioned in the further development of software process in general and the reference model in particular, we conducted a field study in which project managers and process owners were asked to fill out a questionnaire. The field study generated about 30 data points for further evaluation [53]. Furthermore, several literature reviews were conducted to get in-depth information for selected aspects used to back up our results when drawing the conclusions.

Method	Description
Data repository analyses	For all projects in which we were involved, we investigated the repositories that were used to store the project data related to management and development. The resulting information was used to extract key artifacts and information assets to be considered for future SPI projects. The results significantly contribute to the report at hands.
Experiments	Developed methods and tools were also tested in a controlled environment using students as subjects. Since concrete guidelines for conducting SPI-related experiments in such environments (duration, qualification, size of the process, etc.) is not available, we did not only conduct first experiments, but also developed a respective guideline [54], [55].
Monitored projects	For two of the projects from Table 1, we not only took part in the process design and development, but also explicitly monitored the projects. Project *5* is already finished and provided us with a number of insights that were used, e.g. to develop the fist notion of a systematic software process design and development [44] and [59]. Experiences from this particular were reported in [12] and [4]. Project *6* from Table 1 is the latest project in which we currently apply the developed SPI approach.
Tool development and evaluation	In addition to the project work and the (empirical) investigations, the development of tools and their application and evaluation significantly contributed to our work. The developed tools address several phases of the software process life cycle (cf. Sect. 8.1), e.g. the design and authoring support, e.g. [49], [43], [51], [52], or [15], and process enactment, e.g. [42], [48], [50] or [51].

1.4 Outline

The report at hands consists of two parts: In Sect. 2, we present and discuss the related work. In Sect. 3, we analyze the projects from Sect. 1.1 for commonalities, e.g. artifacts that were created in all/in the majority of the projects, practices, and experiences. Section 4 presents the derived artifact model for SPI and SPM. The terminology is introduced, and the artifact model is presented from the SPI perspective (Sect. 4.2.1) and from the SPM perspective (Sect. 4.2.2). Finally, in Sect. 4.3 we discuss triggers that cause SPI projects and programs and initiate the discussion about the determination of successful SPI/SPM. The first part is concluded in Sect. 5.

The second part of this report contains detailed information and models: In Sect. 7, we present the detailed information and models of the artifact model. Each artifact is presented and defined in detail and, furthermore, the dependencies between the artifacts are described. In Sect. 8, we present the complementing processes required to steer SPI and SPM. In Sect. 8.1, we present the basic software process life cycle, which builds the basis for our SPI/SPM approach. Section 8.2 contains the description of a single-SPI project, and refines artifact structures and processes relevant in the artifacts' creation. In Sect. 8.3, we extend the process description to a general SPM-based approach in which we consider SPI programs going beyond single-process adaptation and improvement. Furthermore, we discuss the required management processes and their connection to the SPI-program-hosting organization. Finally, in Sect. 8.4 we present a collection of basic analysis and design decisions, which occurred in the projects (Sect. 1.1), and discuss their implications on the proposed artifact model. In the last section 9, we provide further information regarding a catalog that lists all artifacts from the model, tailoring options for the artifact model, and checklists for planning and assessing the application of the artifact model. Finally, we discuss the options to represent the artifacts and give some recommendations regarding the structuring of the artifacts during analysis processes.

2 Related Work

Software process improvement is considered of high importance for industry and, therefore, is a frequently researched topic. In this section, we present and discuss work related to our approach going beyond the omnipresent maturity models ISO15504 or CMMI and, thereby, structure the publication flora into comparable approaches, general aspects, human factors and success factors, and supporting tools and concrete methods.

Comparable Approaches. Horvat et al. [32] present the PROCESSUS model, which aims at supporting SPI in small and medium companies. They introduce a life cycle model, a set of 17 standard procedures, and a set of 34 standard documents. PROCESSUS itself is based on a synthesis of ISO 9000 and SW-CMM, and refers to the disciplines process automation, process management, supporting activities, software engineering, project management, customer relationship, and introduction/deployment. All these disciplines contain certain processes, which run through a life cycle that contains analysis, definition, training, enactment, and tracing. Wang et al.

[91] introduce a unified framework in which SPI is considered in the context of standardized processes. The proposed model provides a terminology and also provides a formal system model for software developing organizations (SDO), which is used to station SPI development processes, SPI management processes, and interfaces between process defining authorities and process consumption. Nevertheless, Wang et al. [91] only provide terminology and a set of high-level definitions that aid the creation of a consistent terminology, but they do not deliver detailed information about the implementation of SPI in practice. Similar, Joh and Mosly [35] report experiences from a SPI endeavor at Westinghouse ESG. They do not provide detailed information about the concrete implementation of the SPI project, but they show the organizational environment, i.e. the stakeholder groups and their respective top-level activities. Kaltio and Kinnula [38] give a very critical discussion on SPI projects. In their contribution, they complain the usual focus success factors and evaluation, and discus process deployment to be an essential but often under-represented part of SPI initiatives. They report experiences from a practical initiative done with Nokia and conclude that (1) the management of a process (and process parts/assets) is important, (2) that software processes should be considered as "real" products, and (3) similar to products marketing and dissemination is important. Especially Armbrust et al. [4] support last statement: They report on experiences during the deployment of a comprehensive software process into a company. The project to which they refer is also a basis on which our proposed model is built (cf. project 5, Table 1). The perspective, which is taken by Armbrust et al. [4] for the discussion is focused on the organization that owns the process and on the people that are the process consumers. McLoughlin [65] takes the same perspective, and presents a SPI method that is an organization-focused approach aiming at putting more emphasis on business goals and objectives. McLoughlin also presents mappings to standard SPI approaches such as CMMI.

Software Process Improvement in General. Concrete, experience- or evidence-based advice on SPI projects can hardly be found. The majority of SPI-related literature can be categorized into literature surveys on SPI in general, or concrete case studies that report on one particular setting, possibly containing a before-after comparison. Literature surveys are either on general questions, e.g. [84], [68], [78], [26], or on specific aspects, e.g. human factors [6], [3], [90]. Experience reports, e.g. [88], [34], [81], [16], [25], [17], [18] report on concrete SPI projects. Literature reviews are empirical means to provide grounded knowledge, however, most of the studies focus on general questions (e.g. human aspects and collecting success factors) and do not provide concrete advice for initiating and operating a SPI project. Due to the various settings and contexts of SPI projects, even the case studies and experience reports are hard to apply. For each setting, a different project setup is required, which also requires a clear understanding of how SPI projects work in general and what the SPI team should do in response to the actual situation. Only Birk and Pfahl [9] demand an organization of SPI projects in the same way software projects are organized. Another perspective is given by Aaen [1] who basically votes against "formal" SPI programs, and to establish an "end-user SPI" instead.

Human Factors and Success Factors. A considerable number of contributions on SPI focus on human factors and success factors (e.g. terminology [20], training [4]). Taking into account that software processes are a "playbook", which organizes the collaboration of organizations in general and project teams in particular when developing software solutions, human factors have also be considered important. However, the critical – and may be cynical – question, how does this help a process engineering team to initiate, manage, and implement a (new) software process remains unanswered. For example, Stelzer and Mellis [84] provide a list of success factors and conducted a corresponding study to investigate the importance of the found success factors. They conclude the study that the outcomes show factors that should be considered when starting SPI initiatives. However, they do not provide concrete advice how to make use of the findings, e.g. by relating the findings to particular improvement steps. Bin Basri et al. [8] show the management or organizational commitment as an important success factor, even for SPI initiatives in small and medium companies. Berander and Wohlin [6] analyzed success factors and, going beyond the majority of comparable investigations, could show that base-lining and synchronizing software processes have to be considered. These findings do not point to general success factors, but to management-related ones that directly address process development and deployment strategies as also mentioned in Armbrust et al. [4] Process users need to know, which process release is the actual one and when will the next release come – summarized: how stable or reliable the actual process is. Allison [3] provides comparable findings by analyzing several medium-sized teams to investigate the outcomes of a SPI project in relation to the context of the respective teams. Conte et al. [90] conducted a study in which they investigated the human factors learning process, training, motivation, job satisfaction, personality, leadership effectiveness,

making individual decisions, work stress and perception to be of importance when starting SPI initiatives. Such human factors can influence the SPI program, since participants may have concerns, prejudices, or fears. Therefore, process engineers need to know about such circumstances in order to involve the stakeholders appropriately. Umarji and Seaman [89], Green et al. [24] and Riemenschneider et al. [80] focus on the acceptance of SPI programs in general. Umarji and Seaman discuss acceptance from a psychological point of view and propose a metric-based approach to predict the consequences of SPI-related decisions. Riemenschneider et al. conducted a comprehensive study in which they investigated strategies and methods for project managers to overcome developer resistance.

Tools and Supporting Methods. Besides the general questions and those related to human aspects and success factors, a number of contributions proposing specific solutions or aiming at improving particular processes can be found. For instance, [22], [23] propose a tool support for SPI in small and medium companies. In their approach, the dashboard metaphor, as known from software process control centers (SPCC), is transferred to SPI. Their contribution shows support for the top management, for project management as well as for assessors. However, their contribution remains proprietary, as standard process frameworks such as EPF do not support such features [56], [85]. The majority of tools are proposed for supporting specific phases of a software process life cycle, e.g. enactment (e.g., [46], [47], [48], [50], [51], or [42]) or process modeling (e.g., [49], [51], [52], or [43]).

Supporting tools implement activities that support certain steps in SPI projects. Besides the concrete technical implementations, e.g. [5], a number of conceptual methods that are not fully implemented in tools are proposed in literature. In the following, we present a selection of methods aiming at particular SPI activities. Keto et al. [40] proposes a method that aims at improving the requirements elicitation in SPI projects to avoid misunderstandings and contradictions that might result in conflicts. Lavallée et al. [60] state that most SPI approaches focus on improving the processes while ignoring the impacts on product quality. To this end, an approach is proposed that also pays attention to architectures and product quality in the context of ISO 9126. Malheiros et al. [62] propose a method that demands a broader perspective. They discuss SPI in the context of standard processes that underlay an evolution in a continuous improvement process at the organizational level. Nevertheless, the majority of contributions proposing concrete methods are focused on assessments, e.g. [61], [11], [67], [13] or [83].

Discussion. Horvat et al. [32] provide a model that is comparable to the approach proposed in the paper at hands. Of special importance are particular disciplines, e.g. project management and the supporting activities. However although PROCESSUS aims at small and medium companies, the approach defines more than 30 artifacts that are named, but not defined in terms of being represented as a self-contained *artifact model* that provides explanation why certain artifacts have to be created. Furthermore, it is not mentioned how PROCESSUS can be tailored in order to address SPI projects with different scopes, e.g. the fusion of artifacts to reduce the documentation effort for small SPI endeavors. While the bare number of artifacts being created in a SPI project is, more or less, a matter of the project's structure and its operation, the harmonization with the hosting environment is left out of scope. Here, Wang et al. [91], Joh and Mosly [35] and Kaltio and Kinnula [38] name and show the importance of bringing the involved stakeholder groups together. However, Wang et al. and Joh and Mosly provide only superficial descriptions on how to do that, while Kaltio and Kinnula and Armbrust et al. [4] show concrete examples for an involvement. Such an involvement is important, as several studies show, e.g. Berander and Wohlin [6], Umarji and Seaman [89] and Riemenschneider et al. [80]. One aspect that is sporadically mentioned is the tool support. However, process-supporting tools that also address process management are rare. While there exists a plethora of editors and some mature process frameworks [56], tools explicitly aiming at supporting the whole process or process line life cycle can barely found and, if at all, have a limited scope, i.e. [22], [23] (management) or [50] (enactment).

3 Analysis of the SPI-Projects

For inferring the SPI model, we analyzed the SPI projects from Table 1 (cf. Sect. 1.3). The analyses aimed at the organization and operation aspects to answer the following questions:

- Which steps were done in each project?
- Which artifacts were produced each time?

Based on the analysis, we derived a set of key artifacts that we consider important for SPI projects. Furthermore, we could derive a set of techniques and practices that were successfully applied, and which contributed to the construction of the ArSPI model. In order to draw a complete picture, we also list such techniques and practices that did not work properly.

3.1 Practices

Reviewing all the aforementioned SPI projects, we can name the following practices that were successfully applied in (almost) every project:

Table 4 Most common practices extracted from the projects.

Practice	Description
Requirements engineering	As software processes can also be considered as software systems [76], requirements engineering has to be considered important. The fine-grained process requirements as well as the organization-related ones need be collected. In the analyzed projects, workshops and interviews were the preferred practices and, every time, resulted in certain requirement engineering artifacts (documents, models). Only one project did not properly collect the requirements.
Team organization	A clear team organization, especially in the larger SPI projects, turned out to be of special importance. Every team member needs to know his tasks and duties. Communication paths have to be defined; as well known from classic project management. Weaknesses in the team organization result in additional effort and provoke conflicts (one has to have in mind that SPI projects are usually operated in a very sensitive environment, affect individuals, and invite conflicts). In two of the aforementioned projects, the team organization was not stable for several reasons, which caused communication issues in the project and also between the client and the process engineering team.
Deployment strategy	In a SPI project, a clear deployment strategy needs to be defined and communicated. The deployment strategy comprehends a release plan, and planning for pilot projects or – at least – definitions regarding feedback loops. For each of the analyzed projects, the release planning was combined either with pilot projects, explicit feedback loops, or an empirical evaluation. For one project, all these practices were applied.
Management	For every considered SPI project, even for the smaller ones, a set of management activities was defined (again referred to [76]). Project management, configuration management, issue and change management, and release management gave the minimum. Depending on the size and duration of a project, the embodiment of the activities deviated. However, these disciplines were present in each project.
Marketing	For all considered projects, marketing and training built one of the key activities of the SPI projects, e.g. [4], [12]. In an “extreme” example, the process owner created a “process owner avatar” that was reporting the project’s progress via Twitter. Anyway, the usual approach was to organize information workshops and trainings.

The practices that we summarized in Table 4 name the common activities that were performed in the projects. These practices were also considered while creating the ArSPI model, e.g. by paying special attention to define the *process requirements* artifacts, or by linking project management and quality management to the SPI & SPM model (cf. Sect. 4.2, 4.3, 7, and 8).

3.2 Artifacts

Having reviewed the applied practices, we investigated, which artifacts were produced (almost) each time and what were the relevant contents. To this end, we inferred the following list of (generalized) artifacts that could be found each time:

- Process Requirements
- Conceptual Process Design (comparable to an architecture)
- Technical Process Design (comparable to a specification)
- Process Release (comparable to a delivery package)

- Process Life Cycle Support

The list presents an abstraction of artifacts that were produced in every project – sometimes in different shapes, but with comparable content. Starting with project *2* from Table 1, we put more emphasis on the artifacts and started to develop a generalized artifact model, which we improved over time. The artifact model was tested in a student lab [55] and [54], and the "final" model was also tailored and applied in the project *3*, *4* and *6*. The artifact model is introduced in Sect. 4.

3.3 Lessons Learned

Apart from best practices and a generalized artifact model, we can summarize our experiences and give some lessons learned.

Things that worked in each project were:

Aspect	Description
Sound project organization	If the SPI project was organized following the very basic rules of (software) projects, these projects ran quite more straightforward that those in which project organization was missing. Project organization in this context means *at least* to initiate and follow some basic project organization and management procedures of which the most important are: change management, configuration management, release management, and quality management.
On-site workshops	On-site workshops in which the different stakeholder groups are interviewed or involved in the design process proved very successful. Of course, design and review phases can be organized in an asynchronous E-Mail-based style. Anyway, the direct communication and interaction proved to be more effective. In an "extreme" implementation, for project *2* a 2-day initial stakeholder *conference* (about 20 participants) was organized to bring all stakeholders together.
On-site customer *and* on-site process engineer	Similar to on-site workshops, which mostly aim at gathering the process requirements, on-site work also proved successful. Especially in the projects *3, 4, 5* and *6*, several workshops (1 day to 5 days) were organized in order to perform live designs and to discuss the respective outcomes instantly. The same pattern was applied in project *1-RM* in which, e.g. the technology engineering team organized workshops for designing and implementing certain aspects of the reference model, and the compliance team organized workshops on discussing the assessment goals and methods.
Fast delivery	Fast delivery proved very successful. Even if there was only little progress in the process's development, fast delivery enabled the client to monitor the success and to periodically provide feedback and quality assurance. In order to achieve the fast delivery goal, iterative development of the process is necessary, which has implications on the whole project, e.g. planning, task management, release management.
Honesty and toughness	Skillful negotiation was always necessary. It proved successful to be honest all the time and, e.g. to make clear statements which of the client's requirements cannot be implemented. For instance, in the projects *3* and *5* the process engineers had also to support the client-side process owners to fight for the new process as the top-level management had requirements that were either not realizable or contradictory.

In the projects, we also made experiences regarding things that did not work:

Aspect	Description
Instable teams	Instabilities in the process engineering teams showed very disadvantageous. For instance, in the projects *3* and *6* instabilities in the team (incomplete handovers, replacement of a process engineer) turned uncritical projects into critical ones. In one project, the final deadline was missed by several weeks, in the other project, a number of project goals had to be skipped or revised. Also, in project *3* a number of requirements, which were basically already defined, were re-opened by the customer, which caused confusion and tension within the team.

Aspect	Description
Instable requirements	Same as for software projects, the process requirements are the key as they define the target process. In all our projects, requirements were changing with (in some cases significant) additional effort. For example, in the projects *4* and *6* an evolved metamodel needed to be used "on the fly", which caused a stop of the content-related work and pushed the process engineering team back to technical and infrastructure work. In project *3*, in the middle of the project a misunderstood requirement caused a complete change in the process packaging and delivery procedures. Instead of a desktop-based production environment a company-wide production server had to be set-up, which also stopped almost all content-related work.
No design prototypes for "end users"	While prototyping is well accepted in software development, (early) process prototypes should only be delivered with care and only to the client's key personnel. For instance, in the projects *4* and *6* very early design prototypes were delivered, and the client's process owners thought it would be a good idea to collect feedback from the project managers and developers. In project *4*, this decision turned out disastrous as the developers immediately started complaining about the process. Project managers came up with feedback complemented with long lists of change requests. In both projects, crisis meetings and intensive client-internal communication was necessary to heal the generated damage.

The previously presented lessons learned show similarities to software development projects: The project shall be organized, direct communication is important, on-site customers are advantageous, and lacks in the communication and unclear/volatile requirements have to be considered risky.

Consequence. Our lessons learned highlight the importance to organize SPI endeavors as "real" projects. The aforementioned practices and artifacts lay the foundation to create a comprehensive approach in order to provide process engineers with a toolbox to organize a SPI project properly. Furthermore, beyond the single SPI project, our experiences also allow for creating a framework for software process management, which lays the foundation for organizations to initiate and drive comprehensive SPI programs.

4 SPI & SPM Artifact Model

Based on our experiences gathered in the aforementioned projects and further consulting activities, we present an artifact model for software process improvement and management – the *ArSPI* model. The model is based on abstraction and generalization of a number of SPI projects (cf. Sect. 1.1), and the model is also linked to proven knowledge from research and practice.

Remark
All elements of the artifact model described in the following are experience-based; none is artificial. Each part is inferred from SPI projects and evaluated either in practice or at least in student labs.

In this section, we first introduce the required terminology, which is necessary to understand the contents of the artifact model. In the second part of this section, we introduce the artifact model itself. The presentation is here limited to the "bird's eyes perspective". We only provide an overall picture and give compressed information. All details can be found in the sections 7 (artifacts), 8 (life cycle and processes), and 9 (additional information).

4.1 Terms & Definitions

In the following, we briefly introduce the terminology that we use to describe our models on software process improvement and management. Figure 2 shows the terminology as an UML-based [73], [75] metamodel. Please note that we *not* define another or extend a software process metamodel (SPMM; e.g. [64]). The introduced terminology is used to abstract from the diverse metamodels and to provide a general and reusable approach the develop software processes without preferring a particular software process metamodel.

4.1.1 Definitions

Since we present a model that supports software process improvement (SPI) as well as software process management (SPM), we first introduce the definition of these terms.

- *Software process improvement* (SPI) is an endeavor to develop and/or improve a particular software process. The endeavor is organized and managed in a project-like style. In other words, a "SPI project" is a

project in which a concrete software process is developed and/or improved according to specific goals and requirements.

- *Software process management*[6] (SPM) is a collection of management activities at the organization level that support SPI projects (initiating and operating projects, maintenance, measurement, compliance, etc.). To this end, SPM comprises activities from, e.g. project management, quality management, release management, or change management to support initialization and operation of SPI projects in the context of the hosting organization that is interested in the results of SPI projects (e.g. as part of a quality improvement strategy).

4.1.2 Terminology

The core element is the *process asset*. A process asset is defined as a reusable part of a software process that contributes structure or content. We use the term process asset as an abstraction of concrete software process metamodel elements [56], e.g. an *artifact asset* abstracts from the concept artifact, which is differently used in different software process metamodels, i.e. work product in the V-Modell XT, or artifact or outcome in SPEM. Process assets can be defined either formally (using a metamodel) or informal (using prosaic texts). Furthermore, process assets are subject to quality assurance, configuration management, and change management. To this end, we use process assets to provide some common ground to

1. Capture relevant elements of software processes and to
2. Link activities from SPI and SPM to particular elements of a SPI project.

Process assets are means to compose software processes. A software process is – in our understanding – based on a software process metamodel (SPMM [30], [56], e.g. SPEM [74], ISO 24744 [36], V-Modell XT [87]) in which a process language describes the elements and their respective structure, which can be used to create a particular process. Processes can be part of a software process line (SPL; [41], [82], [86]). Software processes as well as entire software process lines can be the subjects of a SPI project.

Example
According to this terminology, e.g. Scrum, Rational Unified Process (RUP), or Kanban are *processes*. The V-Modell XT is a representative of a *software process line* and concrete variants, e.g. those from Sect. 1.1 are processes in terms of process variants of the process line.

The core elements of our terminology model are the *process assets*, the *process*, and the *software process line*. As already mentioned, process assets are the components of which processes and SPLs are composed. They are used to link the atomic steps of SPI/SPM activities to the respective artifacts in, e.g. the process designs. Processes and SPLs are linked to *process tools*, which provide support in terms of authoring processes or building processes (cf. process release, Sect. 0).

Furthermore, processes (especially process releases) serve as deliverables that can be consumed in a software project, e.g. by instantiating a process during the project set-up. All these elements (process assets, processes, etc.) can be referred by other artifacts, which deal with other administrative tasks, e.g. quality assurance, assessments, etc. and, therefore, define the required interfaces to other organization units of the hosting company (e.g. deployment and training schedules can be considered when planning personnel qualification or when attracting new projects that shall use new processes). A process can also serve as "*actual process*" during the requirements elicitation or the analysis phase (e.g. when assessing a process; cf. Sect. 8).

[6] In this definition, we differentiate from Hazeyama and Komiya [29] who more address the design/the tailoring of a particular software process, while we address with the term "software process management" the management of potentially multiple software processes, similar to Münch et al. [69].

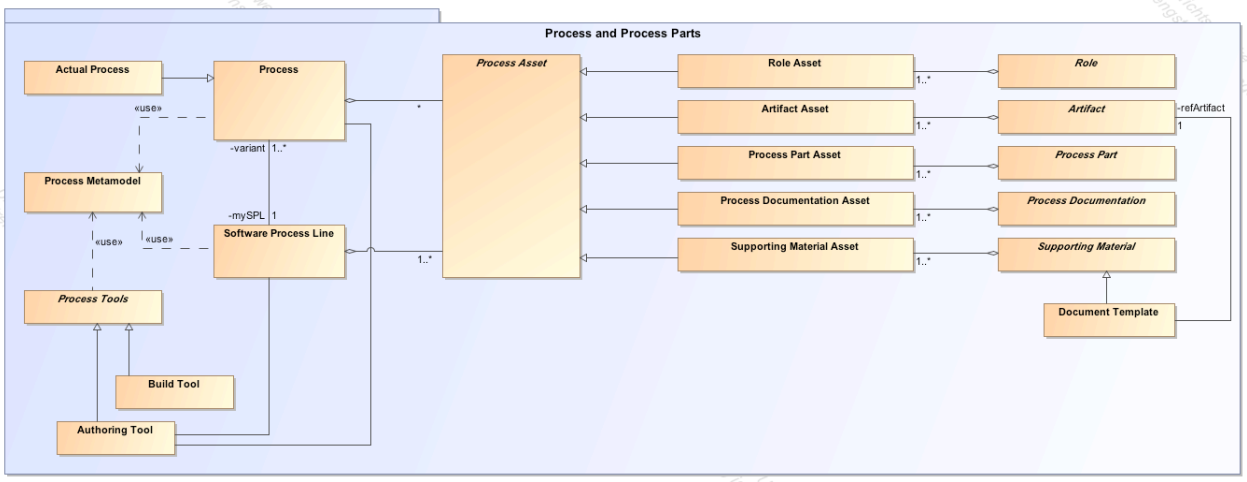

Figure 2 SPI model terminology

4.2 The SPI & SPM Artifact Model – A Bird's Eyes Perspective

From our experiences, we derived a compact model of software process management and software process improvement. In this section, we introduce the model by taking two perspectives:

1. The perspective of a software process improvement (SPI) project
2. The perspective of software process management (SPM) and its embedding into an organization context

At this, software process management comprehends the whole software process-related program/strategy of a company, including all management tasks and interfaces to affected/contributing organization units. SPI is a part of SPM and deals with a particular software process, which is developed, maintained, or improved, in the context of SPM.

In the following, we provide a "bird's eyes perspective" in which we focus on the key artifacts and the basic relations between the artifacts and the corresponding management disciplines.

4.2.1 Software Process Improvement Projects

A software process improvement (SPI) endeavor is a project in which a particular *process asset* or a process is developed or improved in order to meet certain *process requirements*.

Figure 3 shows the overall perspective on a SPI project. The figure covers the SPI project and its respective life cycle Sect. 8.1 as well as the interfaces, e.g. to the project management. The focus of the figure is the set of artifacts. We define five key artifacts that should be produced in every SPI project:

- Process Requirements
- Conceptual Process Design
- Technical Process Design
- Process Life Cycle Support
- Process Release

These artifacts are the *mandatory* results of a SPI project, whereby we do not pay attention to their particular materialization (cf. Sect. 9.4). Furthermore, to provide a flexible and scalable model – as needed in response to the heterogonous SPI project settings – we also show potential for tailoring the model. For instance, the *technical process design* and the *conceptual process design* can be merged to a certain extend (cf. Sect. 9.2.1).

The *process requirements* (Sect. 7.1.1) comprehend all requirements of the considered process and influence the process's conception, the technical design, and also the planning-related tasks, e.g. delivery, measurement, or training. In the *conceptual process design* (Sect. 7.1.2), all requirements are translated into a conceptual non-technical design. To this end, the conceptual design reflects the non-technical requirements to the process and, furthermore, lays the foundation for adding technical aspects. The technical aspects are reflected in the *technical process design* (Sect. 7.1.3) in which, e.g. concrete tool infrastructures or process frameworks are taken into

account. A key artifact, which is often left out of scope, is the *process life cycle support* (Sect. 7.1.4). In the process life cycle support, all definitions and processes are described that support, e.g. the process development, deployment, or training in a SPI project and also during the whole process's life cycle, e.g. process maintenance. Drawing the parallels to software development, the *process release* (Sect. 0) is the final outcome of a SPI project.

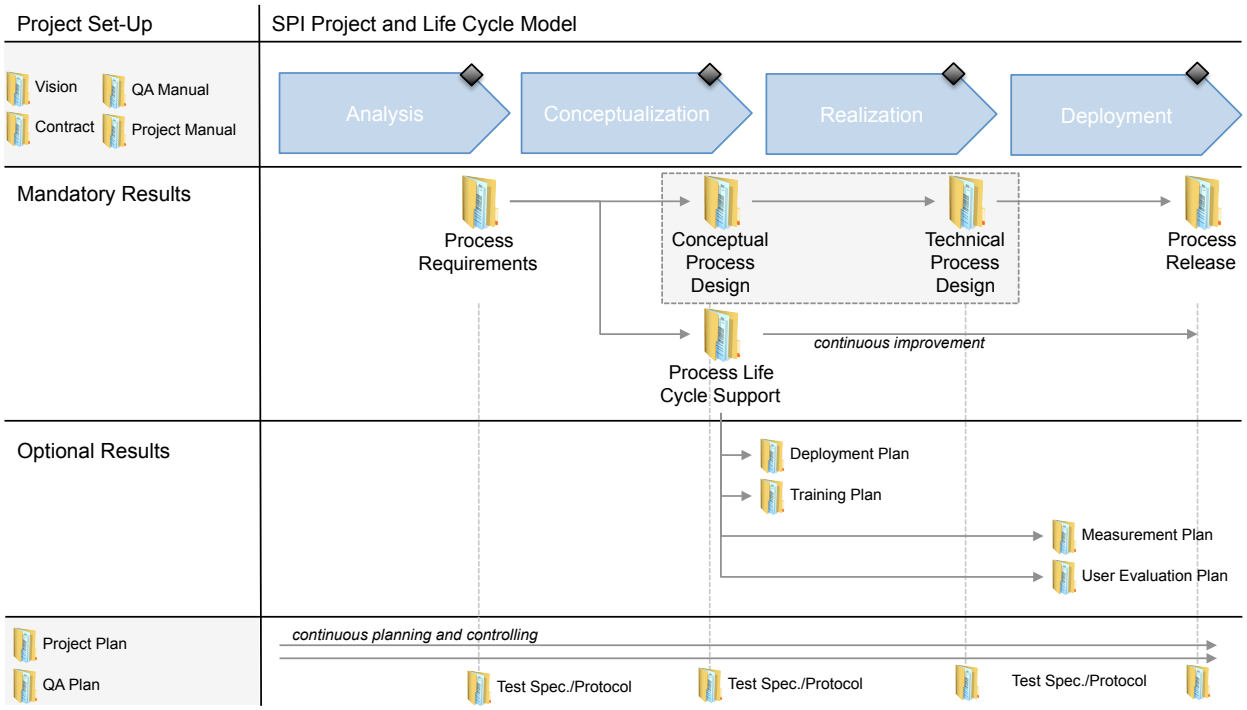

Figure 3 Overall view on software process improvement (SPI) projects.

While the process requirements, the process design documents, and the process release are intuitive outcomes of a SPI project, the *process life cycle support* document is new (and cannot be explicitly found in literature). The process life cycle support is often implicitly mentioned. However, in terms of a sustainable and long-term SPM the process life cycle support is a key artifact that lays the foundation for all activities that are related to, e.g. the personnel's training, process release/deployment strategies, or process evaluation. Figure 3 shows the corresponding artifacts, which are labeled *optional* depending, e.g. on the project's size. For instance, if the trigger to initiate a SPI endeavor is the need to optimize a process for only one project, explicitly created life cycle support documents/plan might be unnecessary since the process is potentially thrown away after the project's end.

Figure 3 also shows artifacts that complement a SPI project and shape the interface to the hosting organization hence SPI requires a management commitment [2]. On the hand, there are the administrative artifacts:

- Vision
- Contract (which also serves as project assignment)
- Quality Assurance (QA) Manual
- Project Manual

In these artifacts, the basic goals and agreements regarding the SPI project are documented (*Vision* and *Contract*). The *QA Manual* and the *Project Manual* comprehend all administrative agreements, definitions, and procedures in order to provide a meaningful project organization and an efficient quality management/assurance in the project (according to Birk and Pfahl [9]). To this end, a project management approach has to be defined, including all corresponding activities, e.g. estimating, planning, controlling, or reporting. Also, a quality management approach needs to be defined in order to organize the quality assurance activities in the project, identification of artifacts to be quality assured, when and how to create test specifications, when and how to test.

Since our model was inspired by many years of work in the context of the V-Modell XT, which considers project management and quality assurance to be mandatory tasks in *every* project, we also demand a minimum of

project management (represented by a *Project Manual* and a *Project Plan*) and quality assurance (represented by a *QA Manual* and a *QA Plan*) for SPI projects. Figure 3 highlights the importance of these disciplines, e.g. by assigning quality assurance artifacts to the SPI key artifacts. In other words, each key artifact from the SPI model has to be quality assured, which means QA has to be planned and organized (constructive QA), and QA activities have to be executed (analytical QA) in order to reach a *quality gate* (each phase of the life cycle model has assigned at least one quality gate).

4.2.2 Software Process Management

While SPI addresses one particular (sub-)process, software process management (SPM) is defined as the set of management disciplines enabling and supporting organizations to initiate (comprehensive) SPI endeavors.

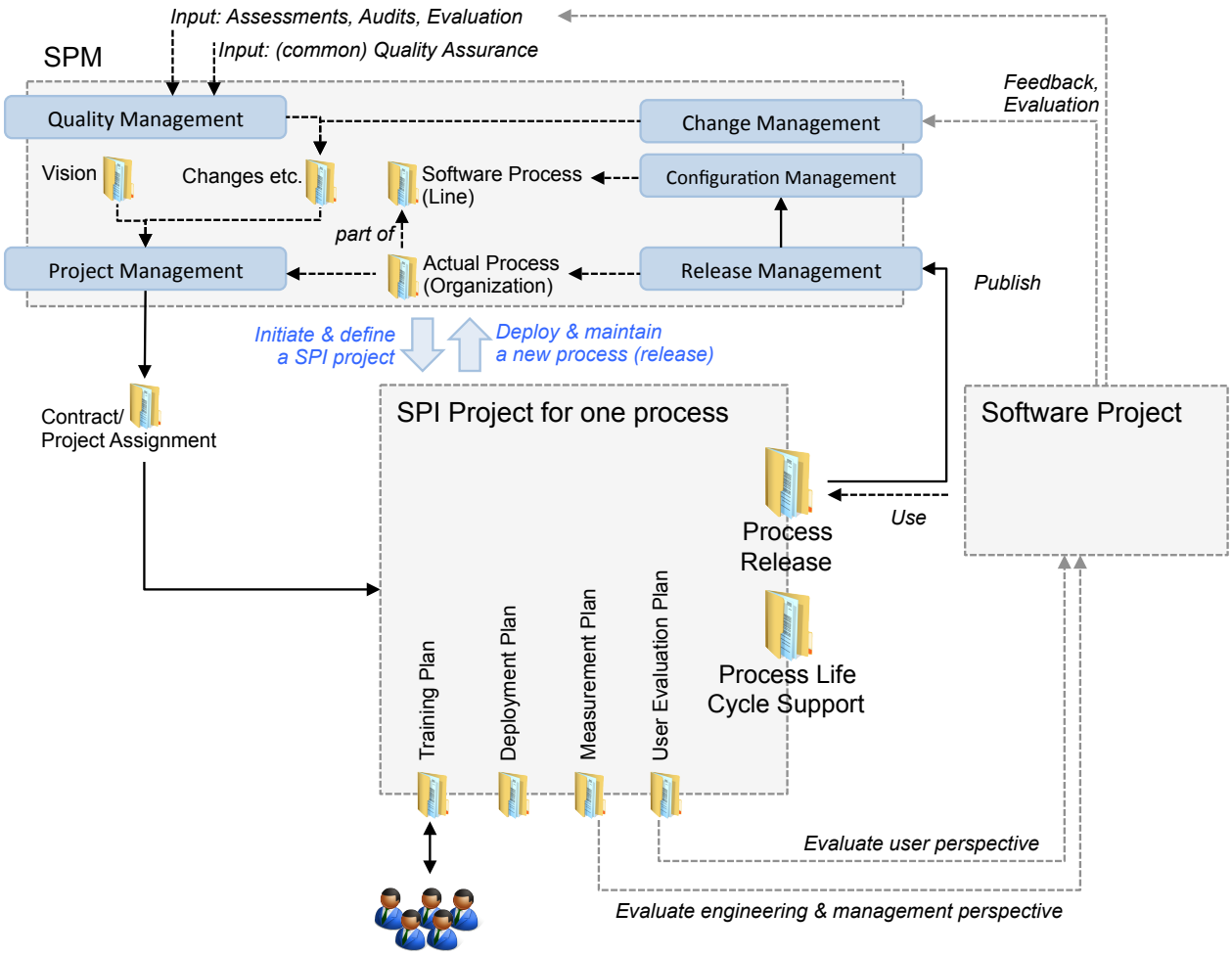

Figure 4 Overall view on software process management (SPM) and its relation to SPI- and software projects.

Figure 4 shows the overall view on software process management and its core disciplines enabling and supporting organizations to initiate and operate single SPI endeavors or comprehensive SPI programs. Figure 4 also shows the relation between a SPI project (Figure 3), the organization that hosts the SPI project, and the software projects that, finally, consume the developed/improved software processes. In the following, we briefly describe the approach in general.

Initiating a SPI Project. A SPI project is initiated (Figure 4, upper part) by the host organization by collecting requirements and creating a vision. If the process under consideration is subject of an improvement, change or feature requests have also be taken into account. Requirements (including change requests) always refer to a particular process variant (precisely to process assets that are consumed by process variants, cf. Sect. 8.3.2.2), which is, e.g. a standard process that needs to be customized, or an already deployed variant (of a process line).

A contract (a project assignment) ensures that all required resources (time, personnel, funding, etc.) are made available. Those are the required inputs to initiate a SPI project.

Outcomes of a SPI Project. The SPI project creates (at least) one process release (Figure 4, middle right part), which is deployed to the client that publishes the process in order to make it available for the projects (release management, Sect. 8.3.2.3). Furthermore, the SPI project generates a process life cycle support documentation, which is also handed to the client. Based on the life cycle support documentation, e.g. qualification and training of the personnel is organized, measurement plans are defined, or long-term developments (represented by a *Roadmap*, cf. Sect. 7.1.4) are scheduled. The measurement and evaluation planning is of special importance: Projects in which evaluations are conducted need to be identified, and KPIs that need to be recorded have to be defined and measured in the projects.

Continuous Improvement. Once a process is released it can be used by software projects that instantiate the process (Figure 4, right and upper part). Projects that execute the process then again provide feedback, and projects are means to collect KPIs for, e.g. a performance evaluation. Feedback and evaluation results serve as input for the change management and also for the quality management. The cycle is completed: change requests or shortcomings (e.g. identified by KPIs) are input for the next improvement iteration.

The brief description of the general approach also outlines the requirements an organization has to fulfill when establishing SPM[7].

Requirement	Description
R1	The organization has to be able to organize and manage projects (resources, funding, and so on).
R2	The organization needs a mature change management (feedback has to be collected, change and feature requests have to be collected, evaluated, decided, and implemented).
R3	The organization needs a mature configuration management (software processes and the supporting material are of considerable size and, e.g. training material has to be consistent with a particular process version).
R4	The organization needs a mature release management (a software process is deployed and then obligatory for projects – projects need to know which process is the one that counts and what does this particular process contain).
R5	The organization needs a mature quality management.

The quality management (QM) is the core discipline in SPM. The QM defines metrics; the QM is responsible for the definition of quality goals and for improving processes in order to reach those goals and, finally, QM hosts SPM hence SPI is often named to be a method of *constructive QM*. For instance, if certain quality requirements need to be addressed by a project in particular or by an organization in general, e.g. gap analyses need to be conducted [66] to derive the demands, areas of action, particular improvement goals, and so forth have to be determined. Furthermore, the QM is also responsible to determine the success of the improvements, e.g. by conducting measurements or user evaluations.

4.3 SPI & SPM Triggers and Success

Having introduced our notion of SPI and SPM, we finally want to answer the question: "Why is a SPI project necessary?" In the following, we discuss the triggers of SPI projects. We also discuss "who" causes SPI projects and, finally, we outline how to determine the success[8].

SPM heavily relies on management decisions made in the company. To this end, a number of organization units and stakeholders are involved (cf. Figure 4). In order to determine the *triggers* of SPI projects we therefore have to pay special attention to three major management disciplines that cause changes, namely:

[7] Those requirements explicitly address SPM. Of course, the particular organization should be able to work in a process-oriented environment and, in an ideal setting, the organization should already be aware of its actual processes.

[8] We explicitly do not discuss questions regarding the return on investment here as, e.g. [10], [14], or [37].

- Quality management (cf. Sect. 8.3.2.1)
- Change management (cf. Sect. 8.3.2.2)
- Release management (cf. Sect. 8.3.2.3)

Each of the named disciplines can cause changes or requirements that lead to SPI projects. For instance, the quality management demands the improvement of the established processes in order to meet requirements given by a standard, e.g. ISO 26262. Such a requirement initiates a SPI project in which the *actual process* is analyzed and necessary improvements are designed, implemented, and deployed. Another example: An already deployed software process is based on a software process line of which a new release of the reference process was published. Such a change causes a new SPI project in which the derived process is analyzed and potentially updated.

Independently, we can differentiate between causes that lead to changes and criteria that influence the SPI project. General questions and corresponding criteria that affect SPI projects are summarized in Table 5 (see Sect. 8.4 for a detailed discussion).

Table 5 General questions and corresponding criteria influencing SPI projects

Question	Criteria
What is the purpose of the SPI project?	• Deployment of a standard process model • Improvement of an already deployed process • Migration to a standardized software process framework
Which kind of knowledge is already present in the organization?	• Generally trained personnel • Generally experienced personnel • "Scuttlebutt knowledge" • Few gurus • External consultants only
Which kind of input material is available?	• Deployed (documented) standard • Documented process (of any kind) • Non-documented process
Which development strategy shall be applied?	• From scratch development ("green field") • Customize a given standard • Create a variant of software process line (reference process)
Which implementation strategy shall be applied?	• Top-down (design and implementation) • Bottom-up (design and implementation) • Top-down/Bottom-up (mixed for design and implementation)
Which deployment strategy is feasible?	• Big Bang • Stepwise (iterative) • Use of pilot projects
How to organize the training schedule?	• Scheduling trainings • Stakeholder group (specific trainings) • Training material development

The general questions and the corresponding criteria address the set-up of SPI projects. Such questions aid a "quick check" of the organization that aims at improving their processes. Some of these questions can be addressed by (comprehensive) assessments, e.g. CMMI or ISO 15504-based assessments/appraisals, especially such questions that aim at determining the current maturity of the organization regarding, e.g. available knowledge, available input material, and so forth.

Such criteria serve the set-up of SPI projects; anyway, SPI needs a *reason*. To outline this necessity, we can ask the following simple question: "What causes a change?" SPI is driven by requirements caused by the demand for changing the current situation. Therefore, we have to answer some questions:

- What is the trigger for a change?
- What is affected by the change?
- How to determine that an implemented change improved the situation?

Triggers for a change are either *external* or *internal*. An external trigger is given by, e.g. a client's requirement or a change in a standard, which is adopted in a company. Internal triggers are for instance new strategic goals by the company's head, identified drawbacks or gaps in the project business, or the deployment of new technologies. Examples and a detailed discussion on the triggers can be found in Sect. 8.3.2.2.

All changes have one thing in common: They affect at least one process asset. The ArSPI model reflects this situation by connecting change management to *process assets*. Our model is based on the terminology from Figure 2. We consider the following process assets:

- Role Assets
- Artifact Assets
- Process Part Assets
- Process Documentation Assets
- Supporting Material Assets

In our model, we map these assets to concepts, e.g. roles and artifacts, which are referred in the *process requirements* and in the *conceptual process design*. To this end, having evaluated a change in terms of having determined the causing/the affected process assets we can create a trace in which we start with the "problem", going to the requirement, to the resulting asset. The kind of the operation that is required to address the change is expressed in the fine-grained structure of the *conceptual process design* (Figure 6). For instance, if a change requires the definition of a new artifact, the customization of another artifact and a role, and the respective relationships, the *conceptual process design* contains the information in the sub-artifacts:

- Planned Adaptations::Organization and Role Model::Customized Role
- Planned Adaptations::Artifact Model::New Artifact
- Planned Adaptations::Artifact Model::Customized Artifact
- Planned Adaptations::Artifact Model::Artifact Dependencies::Artifact to Role Dependencies

To this end, the ArSPI model aids the identification of the process assets being affected by a change to create the respective traces to the requirements. Summarized the proposed model supports by default the following cases (Table 6).

Table 6 Overview: standard changes and cases as initially covered by the SPI/SPM model

Change Class	Cases covered by Sub-Artifacts
Change for artifacts	• New artifacts need to be created • Existing artifacts need to be customized • Existing artifacts need to be removed
Change for roles	• New roles need to be created • Existing roles need to be customized • Existing roles need to be removed
Change for process parts	• New process parts need to be created • Existing process parts need to be customized • Existing process parts need to be removed
Change for process documentation	• New process documentation need to be created • Existing process documentation need to be customized • Existing process documentation need to be removed
Change for supporting material	• New supporting material need to be created • Existing supporting material need to be customized • Existing supporting material need to be removed

Change Class	Cases covered by Sub-Artifacts
Change for process dependencies	Creation, customization, and removal of the following dependency types: • Artifact to artifact • Artifact to role • Artifact to process part • Role to process part • Milestone to artifact • Milestone to process part

The change classes address potentially all parts of a software process, and the proposed model covers – by default – a number of cases that are represented by the process designs and, due to the connection of the artifact model, are linked to the other artifacts from the proposed model.

We now want to address the last question: "How to determine that an implemented change improved the situation?" To answer this question, we have to distinguish two kinds of answers:

1. Is the change appropriately represented and implemented in the SPI project?
2. Does the change affect the efficiency of, e.g. project operation?

The second kind focuses on *qualitative analyses*, which we do not yet cover. Instead, we focus on the first kind. The presented model allows for determining the appropriateness on a structural level, especially the following questions can be answered (most of them in a Yes/No- or checklist-style[9]):

- Are all requirements/changes reflected in the "Planned Adaptations" sub-artifact (was nothing forgotten)?
- For each fine-grained design decision: Are all relevant process assets appropriately listed, designed, etc.?
- For each single process asset:
    - Is the trigger clearly defined?
    - Are all dependencies mentioned?
    - Was the asset implemented, tested, and deployed?

To this end, the model supports the gathering of all relevant information to prepare the qualitative analyses in which the appropriateness regarding the improvement in terms of efficiency can be determined. The presented model allows of structural checks, completeness checks, and syntactical consistency and, therefore, lays the foundation to derive detailed measurement and evaluation regarding the content of the single artifacts.

5 Conclusion & Future Work

The report at hands contains the analysis of several SPI and SPI-related projects, which we used to derive an artifact model and complementing processes to support an organized and directed software process improvement (SPI) and software process management (SPM) – ArSPI. We identified the five artifacts:

- Process Requirements,
- Conceptual Process Design,
- Technical Process Design,
- Process Life Cycle Support, and
- Process Release

as the SPI/SPM key artifacts. These artifacts are described and provided as a UML-based model. The report presents a high-level perspective on the model in its first part, and detailed descriptions in the second part. In the SPI/SPM artifact and process model, we describe structures, contents (partially), and dependencies between the artifacts. Furthermore, we provide rational and explanation why the artifact structures are necessary and meaningful. In order to support the implementation of the SPI/SPM artifact model, we also describe a basic process

[9] During the development of the *Process Development Environment* (PDE; e.g. [49], [51], [52]) we also put emphasis on the options to perform intensive structural checking of completeness and consistency. The experience shows that supporting tools can catch many technical design mistakes, which cause serious failures in terms of missing artifacts or role assignments.

life cycle and a set of activities supporting the artifacts' creation. Finally, paying attention to the different contexts in which SPI/SPM can occur, we present options for tailoring the presented model.

The report at hands lays the foundation to drive further research on SPI and SPM. Hence, the following activities for future work are necessary/planned:

1. Implement the presented model as an applicable software process, e.g. based on EPF or the V-Modell XT.
2. Analyze the implications of the artifact model on standard assessment and maturity models such as CMMI or ISO 15504, and design an extension of these standards.
3. Empirically evaluate the presented approach, e.g. in terms of general feasibility, support for clearly defining measurable success criteria and determination of goal achievements.

Especially the points 2 and 3 are of interest: Since CMMI and ISO 15504 are (almost) free of artifacts and focus on collecting practices and defining activities, the extension of these approaches by artifact models could help the improvement and applicability of such methods. Process engineers and process owners can agree on artifacts reflecting and systematically documenting designs and outcomes in order to aid a long-term improvement and process management.

The 3rd point is crucial and leads to the questions "How can the improvement method improved?" – And how can the improvement determined. An evaluation strategy needs to be worked out in which (a) the feasibility of the presented model can be tested, and (b) the findings can be used to improve the presented model. Such an evaluation strategy thus addresses different aspects of SPI: successful improvement of the process under consideration, and success and appropriateness of the improvement method itself.

6 References

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7 SPI & SPM Artifacts

In the subsequent sections, we introduce the detailed artifact model and the process model, which is based on the software process life cycle. While the artifacts build a compact model of the results being produced in and around SPI projects, the process model addresses single SPI projects as well as entire SPI programs. In order to define a comprehensive software process management, we pay special attention to complementing support processes, e.g. change management, and show how process development/maintenance and project organization are interwoven. The artifacts as presented in this section define the structure of the outcomes of SPI projects (this includes the SPI key artifacts as well as the most important supporting artifacts, i.e. artifacts project management and quality management). Yet, the artifacts need a context, which is given by the processes and activities that are described in detail in Sect. 8.

7.1 Key Artifacts

In this section, we introduce the artifacts of our ArSPI model. We consider the notion of relevant artifacts to be of special importance. Process engineers can use the artifact model to have something solid when talking to process owners and stakeholders. Furthermore, artifacts have advantages regarding the definition and tracking of goals and deliveries (cf. Sect. 4.3). In contrast to Horvat et al. [32] we consolidate our artifact model to put emphasis on the *key artifacts* that are subject to the development and management processes of a SPI project. For each artifact, we describe its purpose, introduce the respective structure (using a UML diagram for the big picture and a complementing table for describing the details), and describe the relationships to other artifacts to explain, why particular information is important and how that information flows through the SPI process. Since we use composite artifacts, we also show the mandatory (M) and the optional (O) sub-artifacts – and information, which is required to tailor the presented artifact model (Sect. 9.2). A complete list of all artifacts is given in the appendix (Sect. 9.1).

7.1.1 The Process Requirements

The process requirements contain all goals, requirements, basic conditions and regulations, and name all stakeholders involved in a SPI project. The requirements lay the foundation for the SPI project and contain every piece of information that potentially contributes to the project.

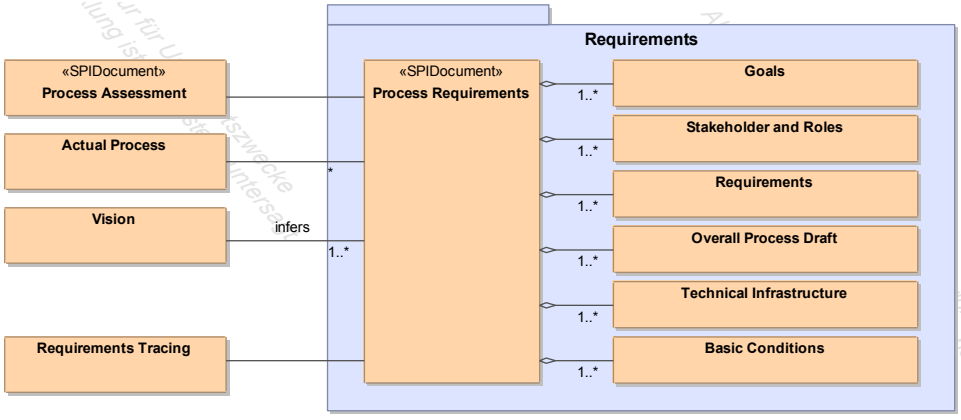


Figure 5 Process Requirements – artifact structure

In Figure 5, the basic structure of the process requirements artifact is shown. The requirements are influenced by the SPI project's *vision*, whereby the *goals* explicitly refer to the vision to address each vision statement (nothing should be forgotten). While the requirements can be created using any elicitation process, a process engineer should have the potential inputs in mind. In most of the organizations, an *actual process* is present – be it explicitly documented or not. Apart from interviews and workshops, the analysis of the actual process is, therefore, an important task to gather information relevant for the analysis of the actual situation and the derivation of improvement goals. Often, a *process assessment* is used to analyze the actual process, the intended/prescribed as well as the process as used by the people.

Table 7 Sub-artifacts composed in the process requirements.

Artifact Type	Kind	Further Information
Goals	M	The goals contain the goals of the SPI endeavor, which are derived from the overall goals as defined in a *Vision*. This artifact is a shared artifact, which is also included in the conceptual process design (Sect. 7.1.2).
Stakeholder and Roles	M	The stakeholder and roles sub-artifact contains all information regarding the stakeholders involved in the project. Stakeholders can become roles, if they either actively participate in later projects or if they have to be involved, e.g. in decision making processes. If such information is available, this sub-artifact can also contain analyses of organization models, e.g. a hierarchy in which a company is organized. At least the names of the stakeholders and roles to be considered should be named to define some basic terminology.
Requirements	M	In this sub-artifact, the requirements regarding the intended process are contained. Initially, the requirements can be documented on a fairly high level of abstraction, e.g. “the process shall provide interfaces to IT operations”. Anyway, all named requirements should provide as much detail information as possible to aid the later creation of the conceptual process design (Sect. 7.1.2).
Overall Process Draft	M	Even in the process requirements, at least a draft of the intended process should be contained. The overall process draft provides a big picture of the intended process model and thus shall contain: • The minimal set of milestones that allows for creating a notion of the process in general (e.g. basic approach, basic decision or quality gates). • The basic artifacts that are produced in the process to determine which artifacts have to be produced in which process stage, and to define the key roles required creating these artifacts. • The top-level processes/activities required to create artifacts and to reach certain milestones. Since the overall process draft is a means for communication, it should be as simple as possible.
Technical Infrastructure	O	If already known, the technical infrastructure of the intended process should be described. The description of the technical infrastructure aims at defining which tools are used to develop and maintain the process, and which tools are required/used by the process consumers, e.g. assistance tools.
Basic Conditions	O	All known basic conditions are also part of the process requirements. Basic conditions are, e.g. legal aspects, demands for a certain maturity level or the demand that the later process can be certified according to certain standards. Basic conditions can be derived from the requirements, but they can influence existing requirements, and basic conditions can also imply new requirements.

The process requirements are essential as they lay the foundation for the whole SPI project. A number of decisions have to be made during the SPI-project-set-up, and all these decisions affect the whole project. A number of examples of such decisions and the respective questions can be found in Sect. 8.4. It is important to have the questions at hands when collecting the requirements as they can help to structure the requirements and to analyze the potential impacts on the SPI project.

7.1.2 The Conceptual Process Design

The conceptual process design comprehends all information, designs, and process asset descriptions that are relevant to reflect the process requirements and to draw the intended process on a conceptual layer without paying attention to any technical realization or infrastructure. From the perspective of a process engineer, the conceptual design is the most important artifact, as it contains all process assets of interest and the basic relationships. The conceptual process design is, therefore, comparable to a software architecture document.

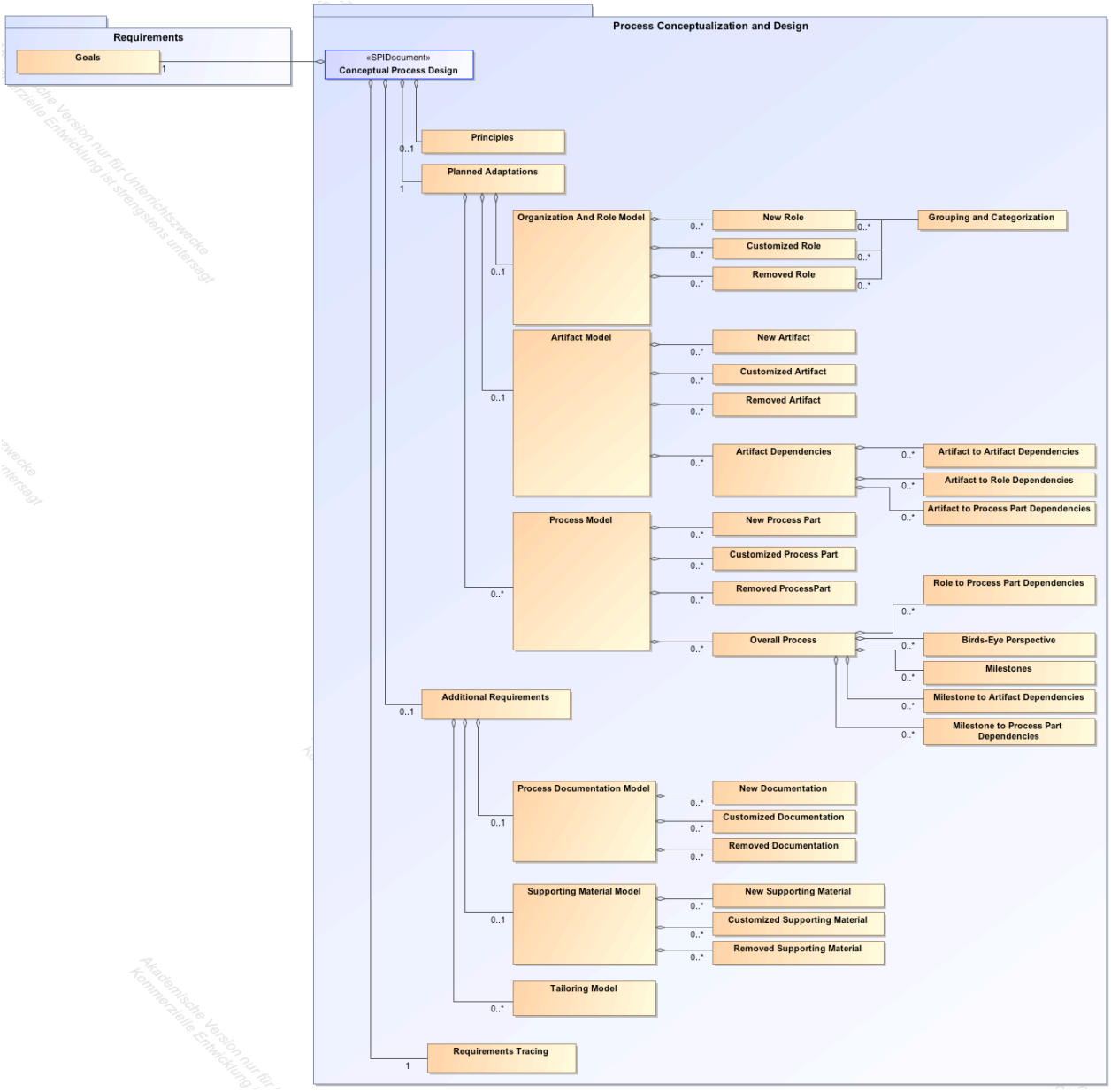


Figure 6 Conceptual Process Design – artifact structure

The conceptual process design is an artifact, which results form extensive analyses, e.g. of the *actual process*. To this end, the conceptual process design is linked to the *process requirements* (see previous section) using "shared artifacts". On the one hand, the goals, which are part of the *process requirements,* are also part of the conceptual process design. On the other hand, the conceptual process design contains a sub-artifact *requirements tracing*, which links the actual designs and the requirements to allow for a tracing. The structure of the artifact *conceptual process design* is shown in Figure 6 and described in detail in the following table.

Table 8 Sub-artifacts composed in the conceptual process design.

Artifact Type	Kind	Further Information
Goals	M	The goals contain the goals of the SPI endeavor, which are derived from the overall goals as defined in a *Vision*. This artifact is a shared artifact, which is also included in the process requirements (Sect. 7.1.1).
Principles	O	The principles aim at defining a set of design principles to be followed, e.g. as much as possible from a given standard process shall be reused.
Planned Adaptations	*M*	*Container that contains all process assets that build the process model.*
Organization and Role Model	O	The organization and role model contains all designs regarding the process roles and models addressing the hosting environment. This sub-artifact is, again, a container that contains further (optional) sub-artifacts: • New roles • Customized roles • Removed roles Each of theses sub-artifacts is created only if it is relevant in the current project context. Furthermore, a grouping and a categorization should be included delivered in this artifact, e.g. a role classification (project or organization role).
Artifact Model	O	The artifact model contains all designs regarding the artifacts (work products) that are contained in the process. This sub-artifact contains further (optional) sub-artifacts: • New artifacts • Customized artifacts • Removed artifacts • Artifact dependencies Each of theses sub-artifacts is created only if it is relevant in the current project context. Furthermore, beyond the artifacts the artifact model also contains the artifact dependencies as a mandatory part (as soon as the artifact model contains at least one artifact, this sub-artifact has to be created): • Artifact to artifact dependencies • Artifact to role dependencies • Artifact to process part dependencies In the artifact to artifact dependencies, the relationships between the artifacts are defined, e.g. creation dependencies (which artifact causes the creation of other ones), or content dependencies (which contents relate to each other, i.e. to model requirements regarding the constancy of artifact exemplars). Artifacts to role dependencies establish the assignments of responsible and contributing roles, e.g. using a RACI matrix. Finally, artifact to process part dependencies model the relations of artifacts to process parts, e.g. activities, processes and sub-processes, or milestones. Depending on the design, a standardized set of dependency types can be used, or a new set of dependencies has to be created.

Artifact Type	Kind	Further Information
Process Model	O	The process model contains all designs regarding the process parts of the process. This sub-artifact contains further (optional) sub-artifacts: • New process parts • Customized process parts • Removed process parts Each of theses sub-artifacts is created only if it is relevant in the current project context. Furthermore, the following sub-artifact is included: • Overall process In the overall process, the relevant information regarding the planned process is contained. To this end, the overall process sub-artifact comprehends the following information: • A bird's eye perspective drafting the whole process • Milestones • Milestone to artifact dependencies • Milestone to process part dependencies • Role to process part dependencies In the milestone to artifact dependencies, the assignment of milestones and artifacts is established, e.g. which artifacts have to be produced and quality assured to which milestones. The milestone process part dependencies assign milestones to further process parts, e.g., as a simple example, phases that are finished by milestones as done in the RUP. Finally, in the role to process part dependencies the assignments between roles and process parts are made, e.g. roles carrying out certain activities or contributing to tasks.
Additional Requirements	*O*	*Container that contains all designs supporting the process's model creation. This sub-artifact is optional and needs to be created only in relation to the current project setting.*
Process Documentation Model	O	The process documentation model contains all designs affecting the process documentation. It names parts of the process documentation that needs to be added, customized, or removed. Furthermore, this sub-artifact contains requirements regarding the presentation of the process documentation, e.g. the "production style" (PDF, HTML) or a style guide.
Supporting Material Model	O	The supporting material model contains reflects all requirements regarding the supporting material, e.g. training material, web presentations, tools, and so forth. It should comprehend information regarding new supporting material, customized material, or removed material.
Tailoring Model	O	The tailoring model reflects the requirements regarding the process tailoring. Process tailoring can address, e.g. a project specific tailoring, particular project characteristics. In this sub-artifact, all the required information is collected that is necessary to define a tailoring model, and a first conceptual draft of tailoring model is described, e.g. a feature tree.
Requirements Tracing	M	This artifact establishes the connection to the process requirements (Sect. 7.1.1). It is a shared artifact, which is also included in the technical process design (Sect. 7.1.3) and, therefore, aids the seamless tracing of the requirements (from the process requirements via the conceptual design to the technical design).

Why are so many sub-artifacts optional?
While the conceptual process design is a key artifact and, therefore, has to be created in a SPI project, many of the comprised sub-artifacts are optional. The explanation is given by the respective context of the SPI project. If a whole process has to be designed and developed, potentially all the sub-artifacts need to be created. If only a smaller improvement is the project's objective, only those parts need to be created that are required. For instance, if an already deployed process is maintained and only a new sub-process (e.g. a new test process) shall be developed, new process parts (activities and so on) have to be designed and assigned to, e.g. existing roles – then, no new roles or new artifacts need to be defined. However, planned adaptations need to be analyzed for their impact to decide which sub-artifacts need to be created. Anyway, the planned adaptations (container) sub-artifact is *mandatory*. Without an adaptation, the project is not a SPI project at all. Only the embodiment of the planned adaptations sub-artifact differs from project to project.

7.1.3 The Technical Process Design

The technical process design refines the conceptual process design (previous section) considering a concrete technical implementation and the tool/tool infrastructure to be used for the process's realization. The technical process design specifies the process and gives detailed (technical) guidance for the process's implementation.

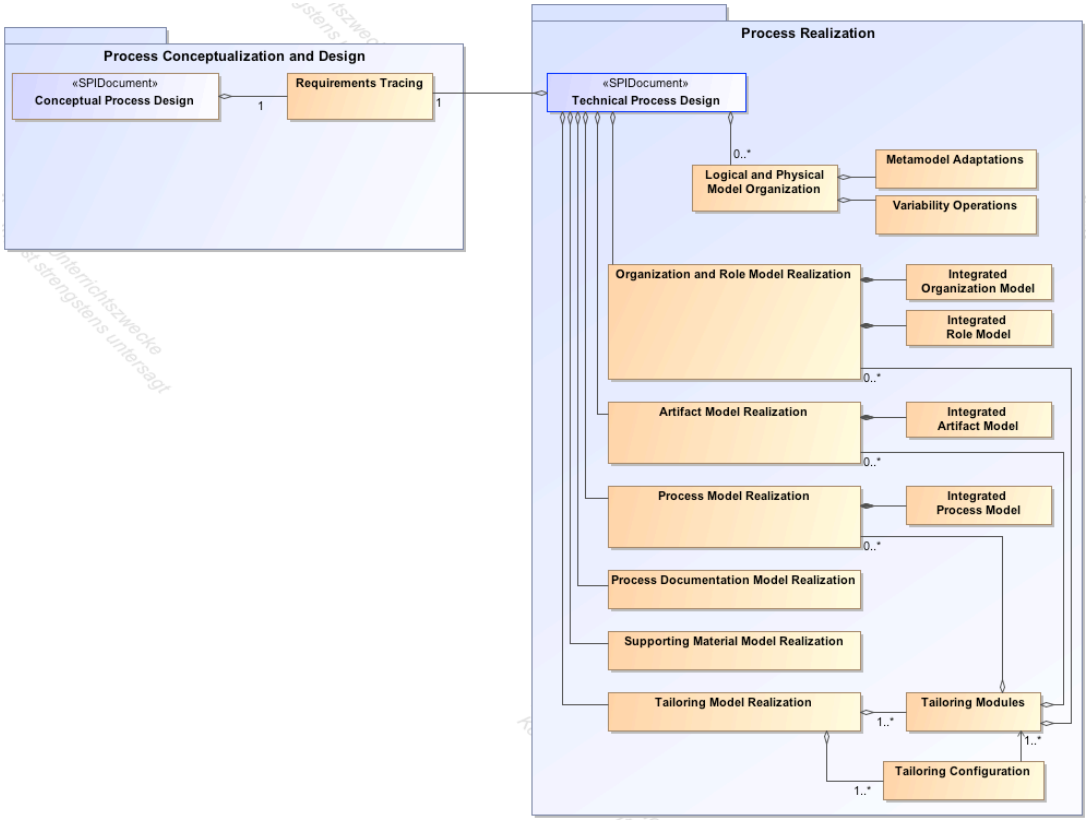


Figure 7 Technical Process Design – artifact structure

The structure of the *technical process design* is shown in Figure 7 and described in detail in the following table.

Table 9 Sub-artifacts composed in the technical process design.

Artifact Type	Kind	Further Information
Logical and Physical Model Organization	M	The logical and physical model organization comprehends all information regarding the technical backbone and infrastructure. First of all, the technical infrastructure has to be defined (if one shall be used), e.g. SPEM, ISO 24744, V-Modell XT. Based on the selected infrastructure and on the requirements, further decisions, e.g. development approach, deployment approach, and so forth, have to be made (or finalized). Furthermore, if the chosen infrastructure is based on a metamodel, decisions have to be made, whether the metamodel needs adaptations to meet all requirements. If the metamodel needs to be customized, all changes, and their respective consequences, have to be documented here. This is of special importance, if the process development is based on a software process line (Sect. 8.3). If the chosen infrastructure allows for creating a process variant using software process line approaches and provides so-called variability operations to copy and adapt standard contents, the applied variability operations also need to be documented. The definition of a technical infrastructure might include a development strategy in which a basic process is adapted and extended. In settings in which legal regulations have to be considered, all changes, even technical ones, might affect the process conformance. Furthermore, each decision in the further modeling processes might be highly influenced. Therefore, one conceptual process design (Sect. 7.1.2) can result in several technical designs that are specific to a concrete technical infrastructure.
Organization and Role Model Realization	O	The organization and role model realization contains the following sub-artifacts: • Integrated organization model • Integrated role model In this sub-artifact the designed roles and the links to the hosting organization are refined. The integrated role model contains all information regarding the actual roles (names, capability lists, categorization of roles (project- or organization-related, internal or external roles) and so forth). This “pool of roles” is embedded into the hosting organization, namely the organization blue print, e.g. a role program manager is in the hosting company a department’s head.
Artifact Model Realization	O	The artifact model realization contains the *integrated artifact model* in which all (relevant) artifacts are listed and related to each other. The artifact model is refined and pays attention to the requirements that are dictated by a selected technical environment. For instance, SPEM would require describing the artifacts as integrated pieces, while the V-Modell XT would allow for an explicit artifact-oriented design in which each sub-artifact is a self-contained and interconnected unit.
Process Model Realization	O	The process model realization contains the *integrated process model* in which all (relevant) processes are designed. The process model is refined and pays attention to the requirements that are dictated by a selected technical environment. For instance, SPEM allows for the fine-grained design of processes and workflows in an UML-like manner, while the V-Modell XT requires the design of hierarchical units called procedure modules.
Process Documentation Model Realization	O	In the process documentation realization model, concrete realizations of the process documentation are designed, e.g. concrete style guides and their implementation, i.e. in a CSS style file for a web presentation or document templates that are used for the later process documentation generation process.

Artifact Type	Kind	Further Information
Supporting Material Model Realization	O	In the supporting material realization, concrete specifications for the supporting material are given, e.g. which document templates shall be provided and how do they look like, which tools are shipped to the process consumers (customized ones or such that need to be developed first), and so forth.
Tailoring Model Realization	O	In the tailoring model realization, the concrete tailoring approach is described. Depending on the opportunities provided by the selected process framework, this sub-artifact describes: • Tailoring configurations • Tailoring modules To this end, tailoring modules refer to other process assets (e.g. roles, artifacts, and so forth) to define reusable building blocks. Tailoring modules are combined in tailoring configurations. The way of defining tailoring modules and configurations depends on the concrete process framework and also affects the development strategy [63]. For instance, the V-Modell XT requires a module-based process realization and, thereby, recommends a particular implementation order [59]. Furthermore, the assembly-based configuration approach is necessary to realize the project-specific tailoring. SPEM, as another example, requires a different approach by explicitly defining so-called delivery processes, which are composed of so-called method plug-ins and processes/capability pattern.
Requirements Tracing	M	This artifact establishes the connection to the process requirements (Sect. 7.1.1). It is a shared artifact, which is also included in the conceptual process design (Sect. 7.1.2) and, therefore, aids the seamless tracing of the requirements (from the process requirements via the conceptual design to the technical design).

7.1.4 The Process Life Cycle Support

The process life cycle support (Figure 8) comprehends all information, agreements, and definition regarding complementing processes that support the deployment, training, and further development of a concrete process. The life cycle support comprehends at least agreements for: training, deployment and further development, measurement and evaluation, and change management.

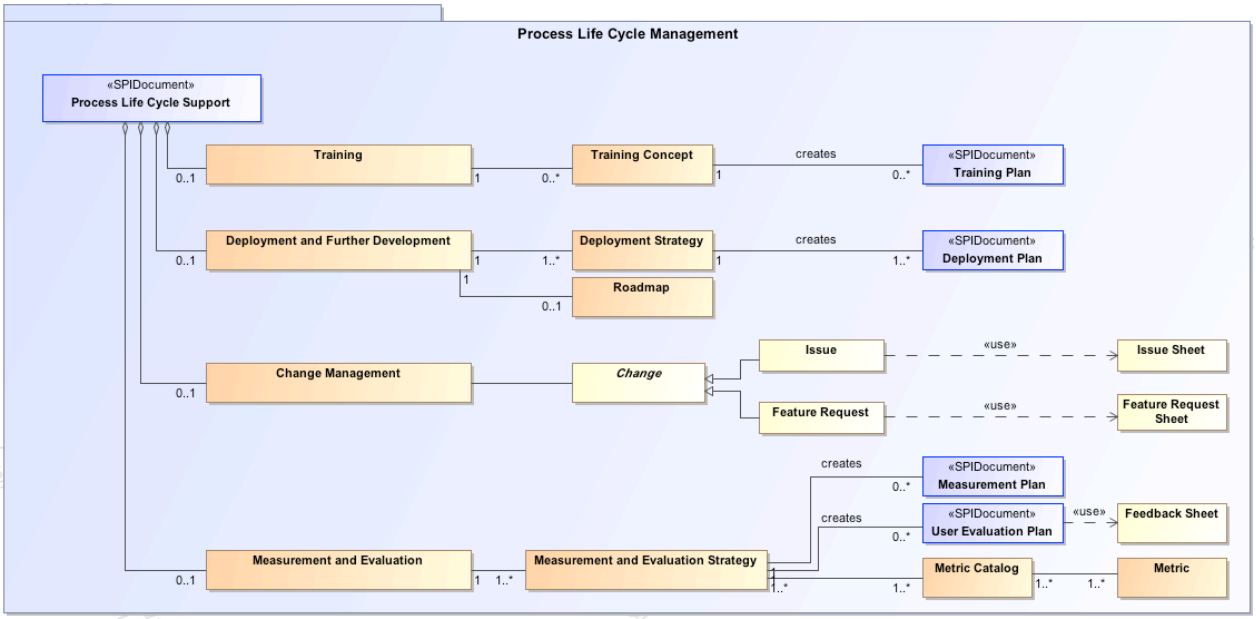


Figure 8 Process Life Cycle Support – artifact structure and related artifacts

The process life cycle support is the artifact comprising all definitions and agreements on methods and processes that are specific for *one particular* process, which is the subject of a SPI project. For each considered process or process variant, a specific life cycle support should be provided. In the context of a software process line, the variant-specific life cycle support documentation should be in line with an overall documentation, which is defined for the entire process line or, at least, for the process line's reference process.

In the process life cycle support, at least definitions have to be made regarding measurement and evaluation, change management, deployment and further development, and training. For each of the named areas, strategies have to be worked out, which serve as the basis for respective planning, e.g. training plans, deployment/release plans. Since these activities complement the process's development and deployment, and consume resources, e.g. personnel to be trained, these activities have to be carefully planned and aligned with the company's day-to-day business.

Two aspects are of special importance: in the measurement strategy, a metric catalog has to be developed. The metrics can be defined, e.g. using a company-wide catalog to allow for a seamless measurement strategy. Second, for each process a long-term strategy – a *roadmap* – needs to be defined. The roadmap is necessary to outline the long-term development of a process, which feature and capabilities will be available, and when. Therefore, a roadmap, on the one hand, forces the management to commit on a SPI endeavor and to provide funding and support and, on the other hand, a roadmap provides security for the projects and project teams.

Table 10 Sub-artifacts composed in the process life cycle support.

Artifact Type	Kind	Further Information
Training	O	Planning regarding the training contains all information and definitions on the required trainings for the process stakeholders. To this end, *training concepts* are created, depending on the project setting, multiple training concepts can be developed, e.g. one concept per stakeholder group. The definitions regarding the trainings affect the *training plan* and, finally, result in the creation of respective *training material*.
Deployment and Further Development	O	Deployment and further development address two aspects: 1. At first, the process has to be packaged and shipped to the consumers, either for testing or for using the process. Definitions regarding the packaging and deployment result in a *deployment plan* (a release plan) in which releases and a respective schedule are contained. 2. Second, if process development is a long-term endeavor, a *roadmap* has to be created in which the long-term goals are defined. The importance of a roadmap should not be underestimated. For instance, in the development of the reference model *1-RM* (cf. Table 1) a roadmap was developed rather late. Therefore, process consumers complained that they had no idea which features will be in the next release and when will the next version be released.
Change Management	O	The change management process is of special importance for a software process, especially if the process under consideration is part of a software process line (SPL). Basically, two kinds of changes have to be considered: an *issue* and a *feature request*. • An issue is a process-related change that is caused by problems that occur during project operation, e.g. a defined practice turns out inadequate and needed to be replaced in every project. • A feature request is a change that represents a new requirement for a process, e.g. to fill a gap that becomes obvious in several projects. The change management is crucial as a change might affect multiple process assets, and dealing with a particular change can cause substantial effort, especially if the change is global in terms of affecting not only a single reference model or variant, but also all variants.

Artifact Type	Kind	Further Information
Measurement and Evaluation	O	In order to determine the feasibility of a software process, a *measurement and evaluation strategy* has to be defined. To this end, a set of *metrics* has to be defined, which are comprised into *metric catalogs*. Depending on the concrete setting, multiple metric catalogs can be defined for a SPI project. The measurement and evaluation strategy results in – at least – a *measurement plan* and a *user evaluation plan*. • The measurement plan aims at determining the process performance in general, e.g. quality of resulting products, schedule adherence. To this end, the measurement plan addresses the process engineers to determine the effectiveness of improvements. • The user evaluation plan aims at determining user satisfaction and to get feedback from the process consumers, e.g. does the process meet the expectations, does the process provide sufficient support. To this end, the outcomes of the measurement and evaluation provide important information to drive the further development of a process variant or the entire process line.

Don't forget…
When defining the measurement plan, it is important to recognize several points: • "Don't measure a project to death!" The measurement plan should be defined in order to meet the project goals. To this end, the goals have to be clearly defined in the process requirements (Sect. 7.1.1). • Only KPIs that are relevant in order to determine the improvements in relation to the goals should be measured.

7.1.5 The Process Release

A process release is a particular process package that is shipped and deployed. Basically, a process release comprehends a collection of process assets (a valid configuration) that is complemented with respective assistance tools, and supporting material, especially the training material.

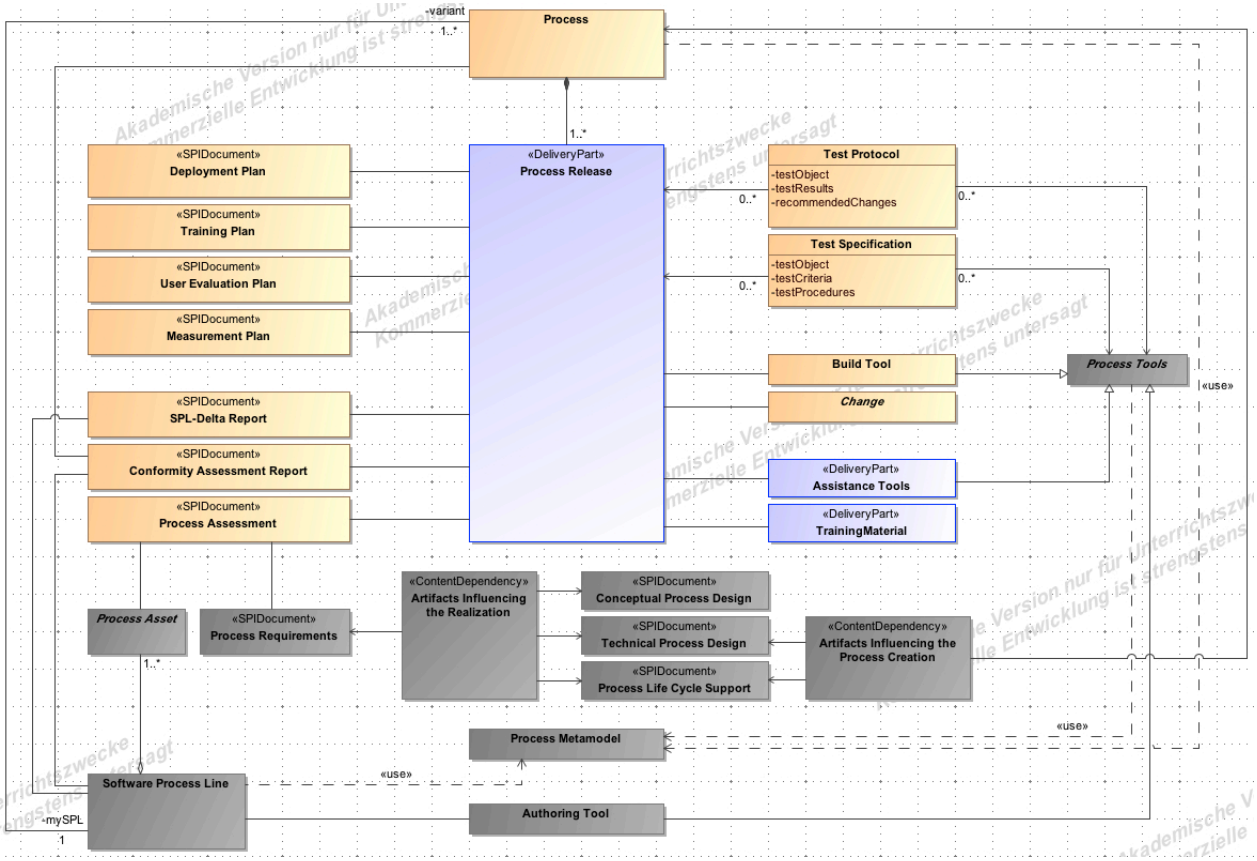


Figure 9 The Process Release – structure and relation to other artifacts

Besides the artifacts that address the process consumers, also artifacts relevant to the management are assigned to a process release. A process is released according to a *deployment plan*. Measurement and (user) evaluation also relate to a particular process release and, furthermore, optionally refer to a reference model, e.g. to determine gaps or improvements. Specific for a particular process release, training has to be planned. To this end, the shipped training material has to be in line with the *training plan* and it must reflect the respective process release. For instance, it does not make sense to ship a significantly evolved process release 2.0, which is complemented with training material optimized for the process release 1.0.

The process release is also a key artifact as it is subject to quality assurance and assessments. During the development of a process, several pre-releases can be deployed to perform quality assurance, e.g. are all roles correctly named, are the artifacts complete, or are the method descriptions appropriate. Depending on the context in which a particular process release was deployed, the quality assurance can contain early user evaluations. Furthermore, several settings may require a certification. To this end, assessments have to be conducted, e.g. to proof that all requirements regarding a particular standard are fulfilled (conformance) or that the considered process meets the demands of a certain maturity level. If the process was created using a software process line, an *SPL-Delta report* should be created. Such a report comprehends all applied variability operations, extensions, and removals of a particular process variant compared to a reference model. For instance, in the context of the German V-Modell XT, such reports aid assessors to determine the degree of conformance to the standard process, which is required to get a certification.

Example

There is general structure for the process release. However, based on the V-Modell XT (Sect. 1.1) the structure of a process release can be as follows:

Installer-based delivery

The installer-based release is shipped as an installer package, which can be installed on a client computer. The installer package (usually) includes [21]:

- All required source files that are consumed by the reference tools
- The reference tools *V-Modell XT Editor* (a tool for editing the V-Modell XT) and *V-Modell XT Project Assistant* (a tool for making a project-specific tailoring, exporting process documentation and document templates)
- Exported process documentation (PDF and HTML format)
- Exported document templates for the available project type variants
- Training material
- Meta data, such as release notes, copyrights, and so forth
- Language packages and corresponding process model sources, exports, and tool configurations

Direct delivery

A "ready to use" package (direct delivery) is a zip-file, which can be extracted and immediately used. Such a archive can be used in a client-side desktop-based "installation" or on a server-based terminal (e.g. in project *4* from Table 1 this distribution style is used). In such a setting, the contents of the distribution package have to be defined, e.g. referred to project *4*:

- V-Modell XT sources (complete sources, incl. reference model, extension model, etc.)
- V-Modell XT variant sources (integrated sources to be used by the process supporting tools)
- Process tools, which include
    - OpenOffice.org installers (V-Modell XT Backend)
    - V-Modell XT reference tools
    - Additional tools, e.g. PET
- Exported process documentation (PDF and HTML format)
- Further project deliveries, e.g.
    - Operations guide[10] (logical organization, approach to edit and create the process, required change management procedure, etc.)
    - Technical process design
    - SPL-Delta report
    - Snapshot of the latest bug list and change status list

7.2 Complementing Artifacts

Beyond the key artifacts described in the previous section, a number of complementing artifacts contribute to a SPI project and to an overall software process management. In this section, we only discuss the most relevant artifacts. A description of the remaining artifacts can be found in the appendix.

The complementing artifacts are on the fringes of the SPI project (cf. Figure 4). These artifacts are relevant in a SPI project and, at the same time, represent the interfaces to further "surrounding" processes. Of special interest in this context are the artifacts for the (general) project management, and the quality management.

7.2.1 Quality Management Artifacts

Quality management[11] is an important aspect that, especially in the context of SPI projects, addresses different aspects. The quality assurance tasks include potentially all process assets and key artifacts of the artifact model. To this end, each artifact is assigned to a *test specification* (defining the criteria for the test, e.g. a review form, a

[10] This particular document was the first instance of the *process life cycle support* documentation (Sect. 7.1.4), which was explicitly requested by a client in order to establish a long-term development and maintenance. After the initial implementation, we also created such documentation for the projects *3* and *6*.

[11] We differentiate between quality management (QM) and quality assurance (QA) in this report. QA comprehends all activities regarding quality assurance that are done in the context of a (SPI) project, while we consider QM to be a (strategic) task at the organization level. In short words: QA = project-level activities; QM = organization-level activities. To this end, SPI and SPM, as part of QM are an organization-level activities.

check list) and a *test protocol* (e.g. a review protocol) to serve the constructive and the analytical quality assurance.

Which test specifications and protocols are created in particular is defined in a SPI-project-specific *quality assurance manual (QA Manual)*. The QA manual contains all information regarding the artifact exemplars that are subject to quality assurance, and which particular quality assurance methods have to be applied. Furthermore, the QA manual also defines the criteria that express what is considered as "good" quality. While the QA manual contains all definitions, metrics, templates, and so forth, the *quality assurance plan* contains the scheduled measures for the respective artifacts. Finally, the *QA report* summarizes the outcomes of the quality assurance and is used for communicating the current state regarding quality, e.g. to the management.

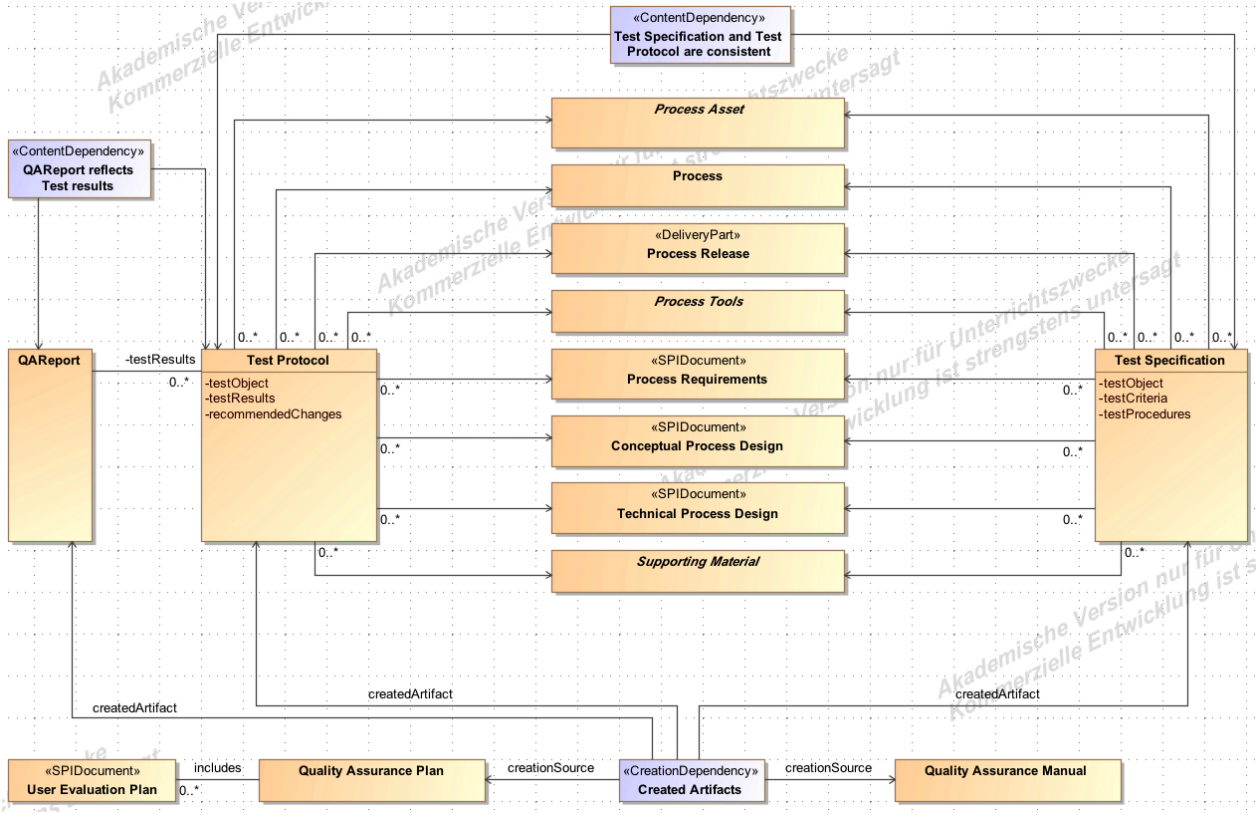


Figure 10 Complementing artifacts from quality management

Example

To highlight the importance of an efficient QA process, we refer to project *4* from Table 1. The project plan schedules two releases per year. This means, a process has to be deployed and tested twice a year. To overcome the effort that comes with, e.g. reading a 480-page process documentation, installing the tools, and so on, the following QA procedures were defined:

- Installation checklists: the process owner (and its team) installs the release and executes some standard procedures, e.g. tailoring, process documentation export, document template export.
- The bug list/the change status list serves as template for the test protocols. The test protocols are used during reading the changed passages of the process documentation. The QA results are then included in the bug list/the change status list (to be considered in the next release).

Since the organization-specific variant of this particular organization contains an improvement and management process for the V-Modell XT variant, no explicit QA manual was written. All the procedures and the relevant artifacts are already mentioned in the process. The bug list/the change status, therefore, serves as instrument to merge test specification, test protocol, and QA reports.

Remark: Until now, no explicit user evaluation was conducted; as the initial deployment was done in 2011 and not enough projects are finished until now to conduct a serious user evaluation. Anyway, the client's process engineering team took part in the field study [53] and reported on their experiences from the SPI project.

7.2.2 Project Management Artifacts

For the project management, we define only a very slim interface (Figure 11) and only define the basic requirements. We require a project to have a formal basis, which is given by a *vision*, a *business case*, and a *contract* (alternatively called project assignment, if there is no external contractor, but an internal process group that is responsible for maintaining and improving the process). Another important artifact to lay the foundation for a meaningful project organization and management is the *roadmap*, which gives information regarding planned releases and the respective "features". The *roadmap* is usually aligned with the *vision*.

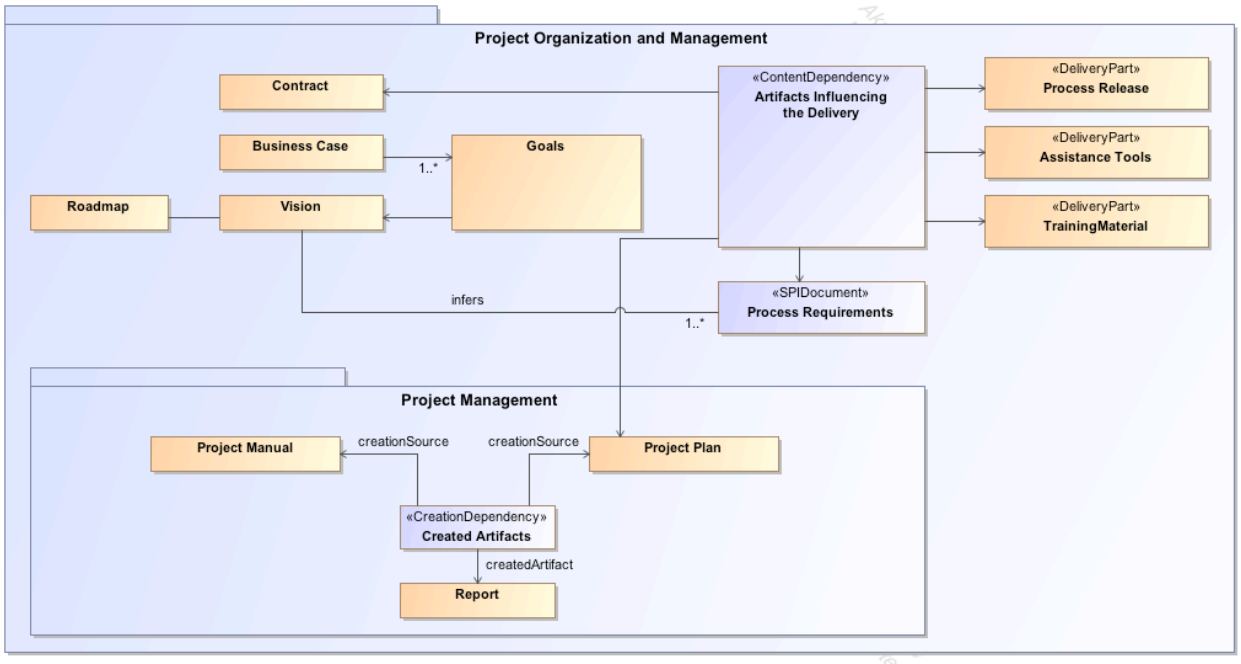


Figure 11 Complementing artifacts from project organization and management

Beyond these artifacts, which are located at the organization level, SPI projects also need a project management. To this end, we define the following three artifacts as the minimal set of project management artifacts:

- The *project manual*: This artifact contains the basic agreements and procedures regarding the project operation, e.g. procedures regarding task management, reporting, project-related changes, and so on.
- The *project plan*: This artifact contains all relevant planning information, e.g. the SPI project schedule, resource assignments, cost planning and controlling, etc.
- The *report*: This artifact represents the reporting procedures in the SPI project, e.g. for project progress.

We explicitly underspecify these artifacts. SPI projects have to be initiated and operated in different contexts and, therefore, different project management practices need to be applied. We just require SPI projects to have this kind of artifacts in order to create solid a basis for a systematically managed SPI project.

8 SPI & SPM Processes

In order to create a meaningful model for the management and the operation of SPI projects, the artifacts described in Sect. 4.2 and 7 have to be complemented with a set of supporting processes that include the creation processes as well as the process interfaces to other management disciplines, i.e. change management. In this section, we show how the presented artifact model can be used.

8.1 The Process Life Cycle

For describing the processes, we first introduce a software process life cycle (SPLC) model in which we draw a big picture of all activities and all key artifacts that have to be taken into account in a SPI project. There exist several life cycle models. For instance, [69] describe a comprehensive life cycle model – the 8-step-model – in order to capture all steps necessary in the development of a prescriptive software process. These life cycles mainly differ in the span of the life cycle (number of covered phases) and the specific focus (prescriptive or

descriptive modeling or process improvement). All these life cycle models follow a typical process, i.e. models can be specified, built, implemented, analyzed, used, assessed, evolved, or rejected.

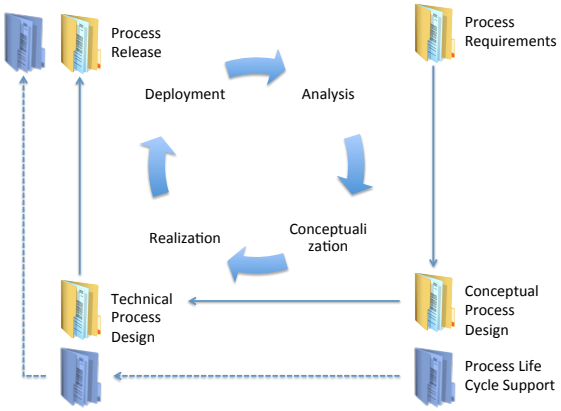


Figure 12 Software process life cycle in a Singe-SPI project

We prefer a simpler model[12], which we developed in the SPI projects, especially in the projects *2*, *3*, and *4* from Table 1. Over the years, the presented model was refined and implemented in several projects and, due to its simplicity, also serves as blueprint used in a lecture on software process modeling [54], [55]. The four-phased SPLC model, as initially introduced in [41], (see Figure 12) consists of four phases:

Table 11 Phases of the software process life cycle model.

Phase	Description
Analysis	In the analysis phase, all process requirements are gathered. To this end, process goals and process requirements have to be determined, and actual processes are analyzed in order to determine the current state of practice. If an existing software process shall be improved, existing process documentation has also to be analyzed. In this phase, interviews, workshops, or audits are the most common techniques to gather the information regarding the actual and the intended processes.
Conceptualization	In the conceptualization phase, descriptive process modeling techniques [69] are used to create, e.g. process prototypes. In this phase, the target software process is designed including, e.g. the selection of modeling techniques/adaptation options, creating drafts of the process to be, and so forth. All those activities are done without paying much attention to concrete technical implementations.
Realization	In the realization phase the creation approach is defined. The definition of a creation approach contains, e.g. the selection of concrete modeling environments and tools, or a realization plan, which is tailored in order to implement, deploy and test the process using the selected technique. Furthermore, the requirements and designs – made during the conception phase – are refined in order to be implemented in the selected (technical) environment. From the management perspective, the realization and the quality assurance plans are created on a level that allows for concrete implementation tasks. Depending on the kind and the complexity of the process model under consideration, the conception and the realization phases can be done in parallel.
Deployment	In the deployment phase, e.g. pilot projects, trainings and concrete deployment strategies are concretized. This includes the rollout of a certain process release or a specific change of an existing process variant that is already conducted. We also subsume in this phase an evaluation of the process by using different means such as assessment, audit, or measurement-based improvement. Furthermore, the deployment phase also contains the “phase-out” of the actual process. How this is managed in detail depends on the particular deployment strategy (cf. Sect. 8.4.6).

These four phases shape the basic SPLC, which is complemented with processes for management and continuous improvement. The simplicity allows for iterative and parallel work on different process assets. In the following sections, we provide more details on the SPLC and its embodiment for different process development and maintenance settings.

[12] Our SPLC is based on the **P**lan **D**o **C**heck **A**ct pattern.

8.2 The Basic Single-SPI Process

When it comes to a SPI project, we distinguish two cases. In a single-SPI project, only one particular stand-alone software process is in the spotlight. The considered software process may be part of a software process line or it is an adapted standard software process. However, such context information is of little or no interest in this particular setting. In the second case, we consider SPL-based software processes in which several additional requirements for the SPI project have to be taken into account (Sect. 8.3).

Figure 12 shows the SPLC model in the context of a single-SPI project. The figure also contains the key artifacts assigned to the SPLC phases (see also Figure 3). In the subsequent sections, we provide a detailed view on the phases. We describe the basic process in detail as it serves as basis for the extended SPL-based SPI approach.

8.2.1 Detailed Perspective on Artifacts

In the single-SPI approach, the SPLC is a strict iterative process. We give a small example in Figure 13 that shows how the SPLC model is instantiated. The first iteration should aim at generating the overall picture of the intended process, and the design artifacts should reflect the respective analyses and designs (at least the process requirements and the conceptual process design should be (initially) created). Furthermore, the initial process life cycle support documentation should – in this stage – comprehend the basic information regarding, e.g. deployment or training strategies. Depending on the selected process development environment, a first prototype can be created. Alternatively, if a final decision regarding the process development environment was not yet made, several prototypes using different environments can be created for evaluation [54]. After the deployment, the process switches again to the analysis phase, whereby feedback becomes now part of the process requirements (in addition to the remaining process requirements, which were not implemented in the previous iteration). Starting with the second iteration, the more detailed work can start (cf. Figure 13).

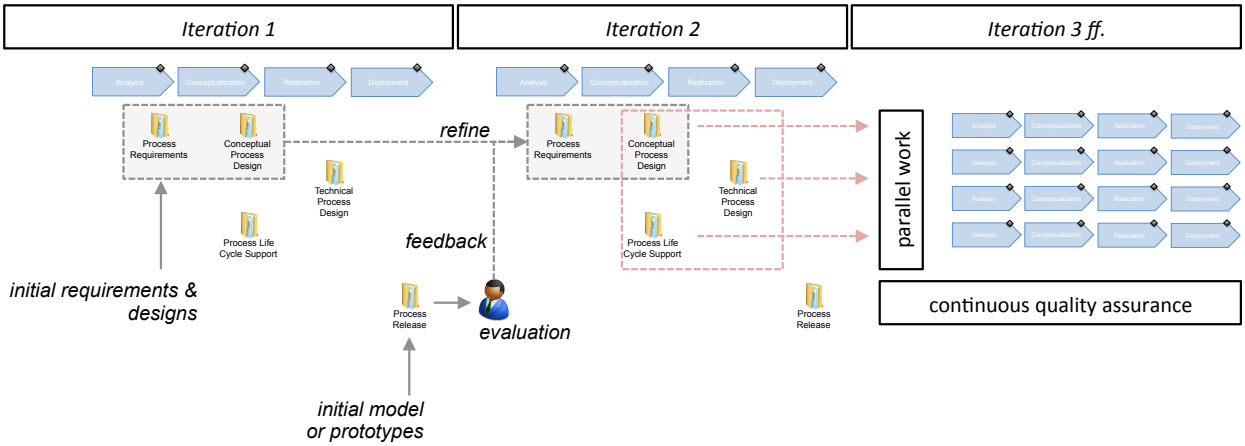


Figure 13 An exemplary development process instance with three iterations and parallel work

The named artifacts from Figure 12 provide each a fine-grained structure (cf. Sect. 7.1) and, therefore, imply certain detail activities as a minimum to create and link these artifacts. In the following, we describe these activities and steps in detail.

8.2.2 Detailed Perspective on the Activities

Figure 14 shows the key activities that are performed in the SPLC to create the artifacts. The relation of the activities and the artifacts is straightforward. For each artifact an activity (an activity group) is defined to create the respective artifact (also, if an artifact contains sub-artifacts, further activities describe the creation of the sub-artifacts). Since the activities are self-describing, we now focus on the activities that are marked as to be refined.

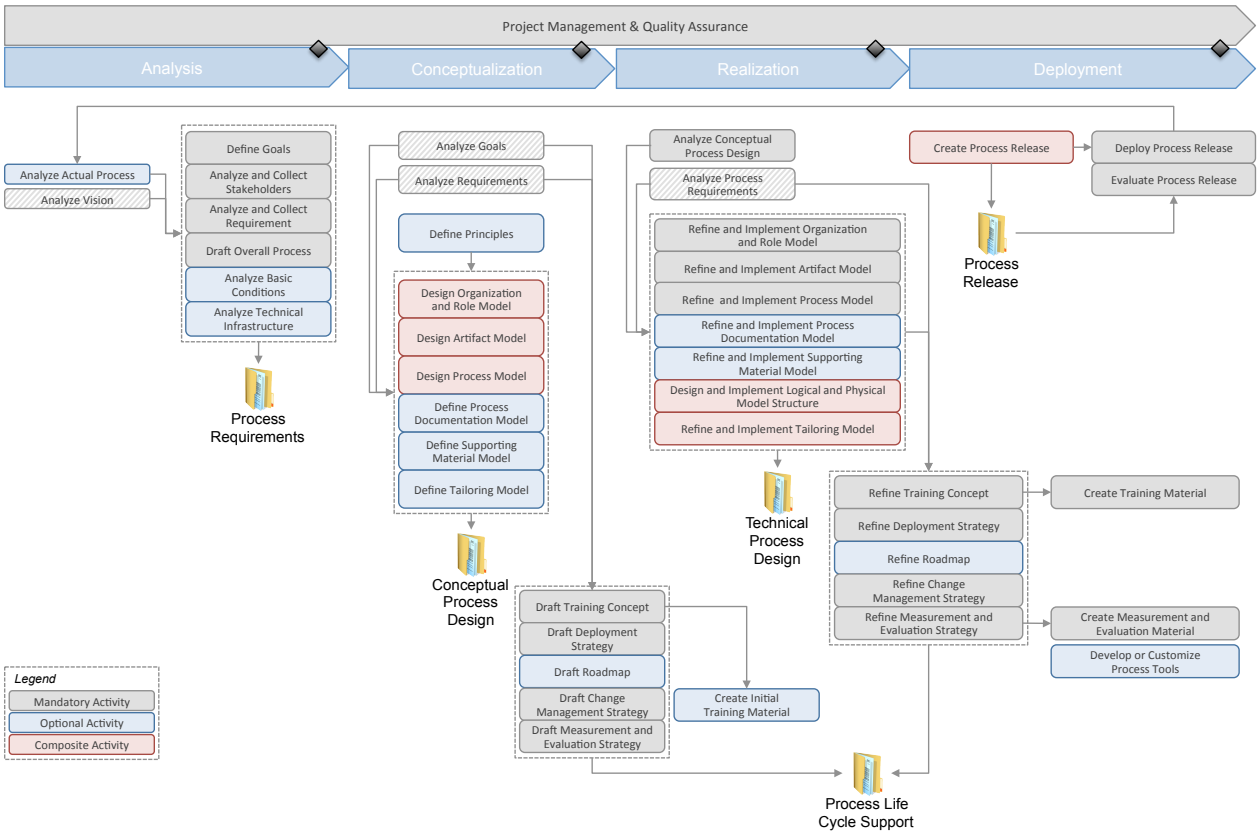


Figure 14 Key activities in the SPLC model for analyzing, designing, realizing, and deploying a process

8.2.2.1 Refined Activities for the Conceptual Process Design

In this section, we describe the refined activities for the conceptual process design.

Table 12 Refined activity: Design Organization and Role Model

Activity	Design Organization and Role Model
The design of the organization and role model is a crucial task. Roles in a process are not only performers of certain tasks, but also a means to reflect a position in a company, which relates to status, power, privileges, and so forth. Therefore, the role model is, usually, the most frequently discussed topic in a SPI project, and often the “right” name is the matter of the discussion. To this end, the following tasks have to executed carefully:	
Define new roles	If necessary, new roles have to be introduced. The analysis of the stakeholders is a good input for this activity, and it emphasizes the importance of elaborating an organization’s structure already in the process requirements.
Customize existing roles	Existing roles can occur in two shapes: 1. Roles already defined in an organization and 2. Roles defined in a process (that is reused). Depending on the goals and requirements, such existing roles have to be customized, e.g. a role that is defined in a process and that is also established in a company, but has a different name has to be analyzed in order to check for differences. In the simplest case, the role, which is defined in the input process, has to be renamed to meet the naming schema of the company (it is easier to rename a externally defined role than to rename a role that is established and staffed).
Remove roles	If an externally defined process is used to provide some basic structure, it usually defines more or different roles than established in an organization. In such a case, roles that are not relevant to an organization have to be analyzed in order to collect their responsibilities, assigned activities and artifacts, and to further check whether a particular role can be deleted without creating an inconsistent process. If a role turns out to be irrelevant (for the actual setting) it can be removed from the process.

Activity	Design Organization and Role Model
Group and categorize roles	Comprehensive software processes may contain dozens of roles. In order to create a manageable process, roles should be categorized and grouped. Hereby, categorization means to create logical containers, e.g. these roles have to be staffed in a project, and those roles represent external stakeholders that are not part of the project team but have to be informed. Grouping is a mechanism for abstraction. For instance, a project manager can be responsible for the entire project or only for a sub-project. However, it does not make sense – and introduces redundancy – to create two roles, e.g. "overall project manager" and "sub-project project manager", since both roles have similar profiles, but only a different context.

Table 13 Refined activity: Design Artifact Model

Activity	Design Artifact Model
Since the result structure of a process is defined in this step, the crafting of the artifact model is a crucial task. If the artifact model is too fine-grained, it limits the freedom of the project team; if the artifact model is too coarse-grained, it does not provide adequate support. Furthermore, if the artifact model is too voluminous, the risk of creating overhead in projects increases, which directly leads to the rejection of the process [77]. The fine-grained design of an artifact model comprehends at least the following steps: • Define new artifacts • Customize existing artifacts • Remove artifacts • Create the artifact dependency model While the first three steps are intuitive, the step *Create the artifact dependency model* is important. The dependency model contains all relationships between the artifacts, including composition, creational dependencies, or content related dependencies. For the conceptual process design, the following dependency groups are important:	
Artifact to artifact	These dependencies define, how artifacts relate to each other, e.g. the process requirements influence the conceptual process design. Such dependencies provide, e.g. rationale why certain artifacts need to be created, or which artifacts need to be in a consistent state. For instance, the definitions in the process life cycle support cause the creation of a training plan and, therefore, provide an example for a creational dependency. Content-related dependencies can be used in quality assurance procedures, e.g. when a delivery in a software project is done the delivery package has to fulfill the requirements as documented in the contract.
Artifact to role	For each artifact, roles either take responsibility or contribute to the artifact's creation. These relationships have to be analyzed and defined, e.g. using a RACI matrix. For each artifact, one responsible role has to be defined, and as much contributors as needed.
Artifact to process part	Artifacts can also be linked to other process parts, especially to milestones (see next paragraph), additional guidance, or phases. These dependencies have to be captured and documented, e.g. those artifacts that are identified as important controlling-relevant or delivery artifacts should be assigned to milestones or quality gates.

The artifact dependencies are a proven and efficient instrument to check the feasibility of a process. For instance, in the projects *3* and *6*, the clients introduced a number of roles. After creating the artifact model, the question for the artifact to role dependencies occurred. For a number of the introduced roles neither a responsibility nor a contributes-relationship could be defined. The consequence was the revision of the role model, and a number of the introduced roles were kicked out of the process model. Another example: In project *6* several artifacts were mentioned to be of special importance. It was tried to assign these artifacts to respective quality gates and to create a draft of the resulting overall process. After a review, the client admitted that the actual draft did not reflect the intended process. A detailed analysis resulted in few new artifacts that comprise the aforementioned artifacts as sub-artifacts.

Table 14 Refined activity: Design Process Model

Activity	Design Process Model
Similar to the design of the role model and the artifact model, the design of the process model consists of several steps: • Define new process parts • Customize existing process parts • Remove process parts • Define the overall process While the first three steps are intuitive, the step *Define the overall process* consists of further important steps: • Create the Bird's Eye perspective • Define milestones • Define milestone to artifact dependencies • Define milestone to process part dependencies • Define role to process part dependencies The creation of Bird's Eye perspective is important to always have the big picture in mind, otherwise the risk of being lost in details increases. The definition of milestones is crucial. For each milestone, it has to be defined which artifacts have to be finished and quality assured, what are the goals of a milestone, and what are the criteria that define whether the goals are reached. The assignment of artifacts to milestones is part of the artifact dependency network and, therefore, is designed to be a self-contained step.	

8.2.2.2 Refined Activities for the Technical Process Design

In this section, we describe the refined activities for the technical process design.

Table 15 Refined activity: Design and Implement the Model Organization

Activity	Design and Implement the Model Organization
The logical and physical organization of the process model depends on the decision which process engineering framework [56] should be used for realizing the process. In this step, it has to be decided, how and where, e.g. templates have to be stored. Furthermore, process-engineering frameworks may require a particular directory structure in which the contents have to stored, e.g. the V-Modell XT [59]. Another requirement could be to extend a process engineering framework, e.g. to customize the metamodel [85]. Such customizations have to be documented, too.	

Table 16 Refined activity: Refine and Implement the Tailoring Model

Activity	Refine and Implement the Tailoring Model
If the selected process-engineering framework supports process tailoring, the tailoring model has to be defined. In the tailoring model, the single tailoring modules have to be designed as well as the tailoring configurations, which refer to particular tailoring modules. The design of a tailoring model is a challenging task. A process engineer has to ensure that in a particular tailoring configuration no important process asset is missing and, furthermore, only the relevant process assets are contained to avoid overhead. In addition, a tailoring configuration has to be consistent. The design of a tailoring module highly depends on the tailoring concepts provided by the selected process-engineering framework, e.g. SPEM and the V-Modell XT follow completely different approaches. Therefore, no common guideline how to design a tailoring module can be given, apart from the following suggestions: • Consider a tailoring module as a reusable building block that contains a set of highly cohesive process assets, e.g. a particular test approach could be a self-contained tailoring module. • Consider a tailoring module as a low-level configuration, e.g. a tailoring module can serve as connector to link several other tailoring modules, for example a module for coding and one for testing. • Consider a tailoring module as means to provide variability for a project-specific software process, e.g. provide a tailoring module for the management of large-scale projects and another one for small projects, or a tailoring module that defines a waterfall-like approach and for another setting an iterative approach.	

8.2.2.3 Refined Activity – Create the Process Release

A shippable process release is the goal of an iteration of the process development process. To create a process release, all delivery parts have to be collected and packaged.

For a process, several releases can be created, each consisting of a number of process assets and tools. For a particular process release, especially the assistance tools and the training material need to consistent to the release.

8.3 The Extended Software Process Line SPI Process

As mentioned in the previous section, we consider two scenarios in which we operate SPI projects. In this section, we extend and apply our SPLC model to SPI projects that are operated in the context of a software process line (SPL; e.g. [41], [82], [86]). To this end, we describe the setting using the example from Figure 15. In this example, the SPL consists of a *reference model* (RM), two process *variants* A and B, and a process variant A1, which is a variant that is build on another variant (A). Notably, we consider three variants of which two build a hierarchy. This setting is based on the process variant hierarchy of the V-Modell XT (cf. Figure 1; [85]).

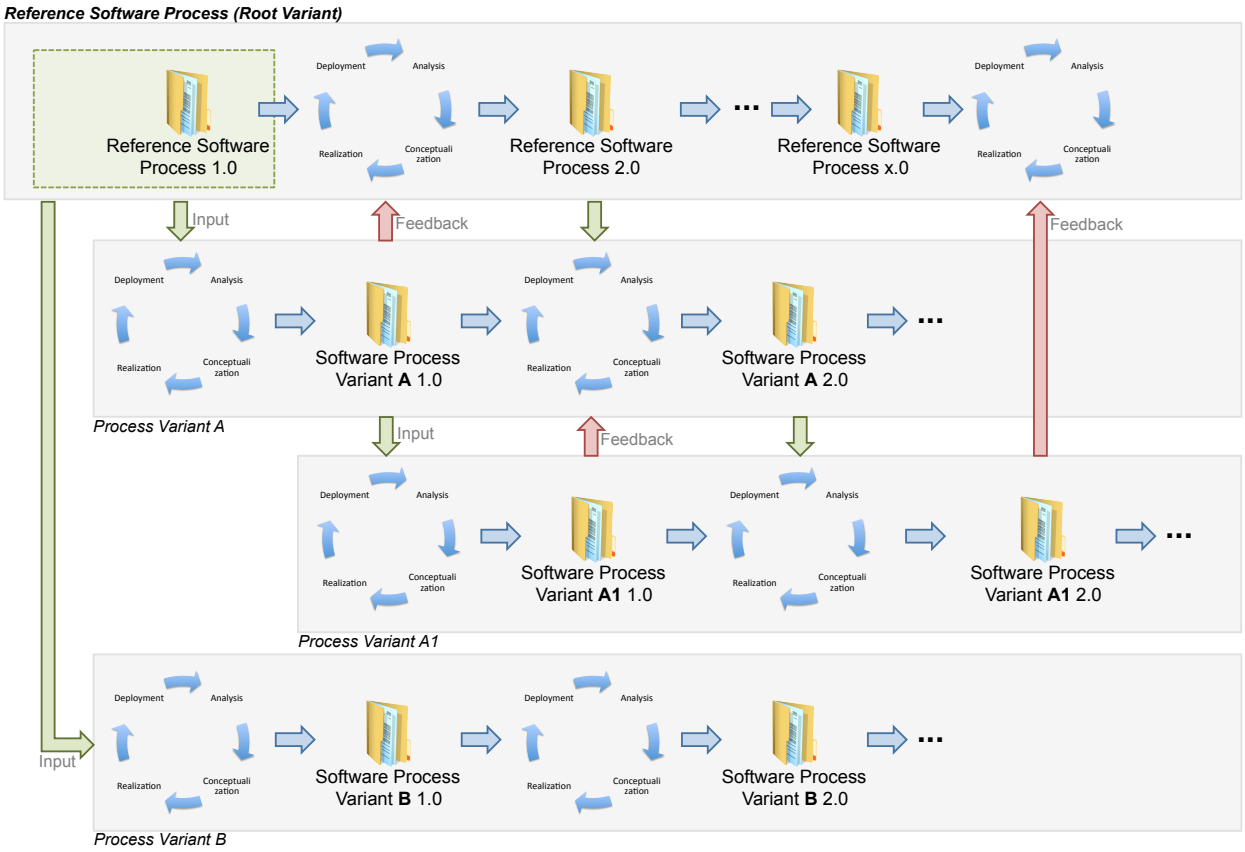


Figure 15 Software process life cycle in a software process line-based SPM

The adaptation of the SPLC model to the SPL-based SPI projects is straightforward. Figure 15 shows that for the reference model and for each variant an own SPLC is instantiated. Therefore, each variant iterates through the life cycle. For instance, if the initial release of variant A is created the reference model on which the variant is based serves as (a) actual process and (b) as basic condition (cf. Figure 14). Furthermore, when it comes to a further development of the reference model a variant can provide input to the RM development and, therefore, also becomes a part of the actual process to be analyzed.

Summarized, the basic SPLC model can basically quite simple be transferred and applied to SPL-based SPI projects. The major difference is in the management processes that have to be applied to:

- Maintain the reference model
- Develop and maintain process variants
- Establish feedback loops between RM and the variants and vice versa

In the following, we discuss the specific requirements of SPL-based SPI projects and pay attention to the respective management tasks.

8.3.1 SPL-based SPI Projects – Specific Requirements

In order to extend and apply the SPLC model to SPL-based SPI projects, we have to pay attention to the specific requirements of SPL-based processes. We discuss these requirements using the example from Figure 15. In the figure, a reference model and a number of derived variants are shown that have dependencies between each other. The most obvious dependency is a parent-child relationship between a reference model and a variant, whereby a variant can also serve as reference model for further variants (cf. Figure 15, variant A and variant A1). Such a relationship implies several requirements:

Requirement	Description
R1	Evolutionary changes of the reference process need to be propagated to the variants.
R2	Changes and differences need to be recognizable and easy to adopt.
R3	Feedback from single variants must be available for other variants, too.
R4	A global notion of process quality needs to be introduced, e.g. by defining a conformity term.

The previously listed requirements are still challenging tasks. For instance, much effort was spent in determining evolutionary changes in comprehensive software processes. The group around Münch [70], [71], [72] worked on this problem in the context of the V-Modell XT. Their results provided insights into the evolution of a process and, at the same time, analyzed the evolution of a reference model and its impacts to derived process variants, changes in a variant that are affected by a change in the reference model, and changes of several variants in relation to a reference model to compare parallel evolution of reference models and variants. However, although the analyses were comprehensive and informative, the decision which changes directly affect a particular variant and thus have to be implemented still had to be made by a process engineer.

In response to this particular situation, e.g. the V-Modell XT's metamodel was revised in accordance with the process line approach in which SPL-based variants are created an explicit set of so-called variability operations, which – under optimal conditions – allow for automatic updates [86].

While the first two requirements are more of technical nature and, therefore, can be addressed using a respective modeling and design approach, the other requirements address organizational questions. Establishing a feedback loop that allows for providing the reference model with feedback from the variants, especially when problems in the development of a particular variant occur, requires – at least – a mature change management. For instance, in project *2* from Table 1 several technical issues and shortcomings in the reference model *1-RM* were revealed that caused certain improvements in the variants backbone, which were later considered in the improvement of the reference model. If working in the context of a process line, the reference model defines the basic contents and structure and, therefore, gives the basic notion of the SLP-wide quality and conformity requirements. Such quality requirements are important, e.g. to ensure the comparability of certain process variants (for instance, if project member work in different projects), or to allow for certification.

The SPLC supports those requirements by using the artifact model. For instance, in order to determine adaptations and extensions of a reference model, an *SPL- Delta report* is assigned to each process variant. This report contains a summary of all applied variability operations, affected process assets, and a rationale. On the one hand, this report documents the differences between the reference model and a particular variant and, on the other hand, this report supports the determination of the degree of conformance, e.g. by rating the applied variability operations whether the application is noncritical or subject to further quality assurance. Furthermore, the report reflects the actual implementation and allows the comparison with the planned customizations and hence is also an important input for the quality assurance. In order to establish communication and feedback loops, the artifact model defines several artifacts dealing with change management, which is an integral part of a SPI project. Furthermore, artifacts dealing with process assessments and quality management are also part of the artifact model (more on this topic in the next section).

8.3.2 Management Processes

SPI projects have to be organized and implemented according to software development projects. To this end, a number of management processes have to be defined and implemented, especially when dealing with SPI en-

deavors that are based on software process lines. As single-SPI projects can usually operated in a rather pragmatic/straightforward management style, SPL-based projects require mature:

- Project management
- Quality management
- Change management
- Configuration management
- Release management

In the following, we focus on the quality, change, and release management for SPI projects.

Important
In the following, we describe the management processes using the artifacts from our artifact model. The description is intentionally *underspecified* and focuses on the required artifacts. It is the responsibility of the implementing organization to fill the gaps, especially on the organization layer as we assume corresponding processes to be already in place.

8.3.2.1 Quality Management

The quality management processes (incl. quality assurance) are based on the QA-related artifacts (Sect. 7.2.1). We distinguish two basic perspectives:

1. Overall quality management
2. Quality assurance

The quality management (QM) relates to the whole process or the entire process line. On this level, several artifacts might be necessary in order to define an appropriate QM:

- Process Assessment
- Conformity Assessment Report
- SPL-Delta Report
- Metric Catalog (incl. Metric)

The *metric catalog* (and also the *metric*) is an artifact that links the QM with project and process management. The metrics and KPIs are conducted in projects; the QM defines the initial definitions, which metrics and KPIs are of interest. To this end, the organization that operates SPI programs needs to establish measurement programs regarding project- and process performance that includes the definition of metrics and the measurement in the projects.

As part of a measurement program, *process assessments* serve as reported activities regarding, e.g. the process performance (determination of maturity levels, gap analyses, etc.). In special cases, e.g. conformance or compliance to certain standards or customer requirements needs to be proved, an assessment addressing conformance or compliance needs to be conducted and documented in a *conformity assessment report*. Both assessments refer to the *measurement and evaluation strategy*, which is defined in the process life cycle support documentation (Sect. 7.1.4), and to the *process* or the *process line* (Sect. 4.1.2).

In addition, especially again in the context of a conformity check of a process variant in a SPL-based setting, a *SPL-Delta report* explicitly documents changes that were done using planned operations as defined by the process line. The application of such variability operations has to be declared in the *technical process design* (logical and physical model organization; Sect. 7.1.3), and refers to a particular *process release*, the *process* or respectively the *process line*.

In order to implement a software process management (SPM), an organization needs to implement processes that support:

- The definition of metrics as well as a corresponding measurement
- Measurement and evaluation activities that address the organization level, and that can be instantiated in the projects to be monitored
- Determination of deviations of process variants in a process line in order to measure conformance, compliance, etc.

On the SPI project level, we demand as *minimum* the creation of the following artifacts in order to establish a quality assurance for the project:

- Quality Assurance Manual (QA Manual)
- Quality Assurance Plan (QA Plan)
- Test Specification
- Test Protocol
- Quality Assurance Report (QA Report)

The *QA manual* is the playbook, which contains all definitions regarding the QA activities in a SPI project. Such definitions comprehend the process assets that shall be tested as well as the corresponding test methods and the test criteria. Test criteria should be defined on QM level and context-specific transferred to a project, e.g. a subset of metrics. For every process asset that is mentioned in the QA, a *test specification* has to be created (the detailed definitions are documented in the *QA manual*). The respective *test protocols* document the test procedure, e.g. a review for a process documentation asset, a checklist for a check regarding the completeness of artifacts or activities. Since the *QA manual* names all assets that have to be considered for QA activities and *test specifications* contain the particular tests, all these activities need to be included in the project's schedule. This is the task of the *QA plan* in which the QA activities are scheduled. Finally, the *QA report* documents the overall project status regarding the quality aspects.

The *QA manual*, the *QA plan*, and the *QA report* are artifacts that build the interface to the project management activities.

Remark
There is one QA activity that often occurs in SPI projects: the user evaluation. Actually, the user evaluation is part of the measurement program. Anyway, such evaluations are often done in combination with QA measures (reviews). To this end, the *user evaluation plan* is also related to the *QA plan* if such activities are done in a project. One has to differentiate between a "general" user evaluation in the context of the "global" measurement and the user evaluation in a particular improvement project.

Further details regarding fine-grained QM and QA activities are modeled in the complementing process model.

8.3.2.2 Change Management

For the change management, we selected a very simple approach, which also worked fine in our projects. In the change management, which is part of the *process life cycle support* documentation (Sect. 7.1.4), it has to be defined, what kinds of changes exist and how to handle occurring changes. To this end, the artifact model contains only three artifacts:

- Change (abstract element to link further artifacts)
- Issue
- Feature Request

A change always refers to a process asset. An *issue* is a problem with the process or any of the contained process assets. A *feature request* is also a change request, which aims at including a new feature to a process.

Change management has to be considered on two levels, again. At first, change management to be defined in the context of the SPI project, e.g. a review requires a change to be implemented in the next iteration (Figure 16). This kind of change management is a part of the project organization, which is documented in the *project manual* (Sect. 7.2.2).

The second "style" of change management is the management of the evolution of a software process or of the entire process line. An example is given in Figure 15. In the figure, a reference process is show that serves as basis for several variants. Change management in this context has some additional tasks:

- Evolutionary changes of the reference model have to be propagated to the derived variants
- New developments or changes from certain variants have to be checked, whether they could provide benefits to the reference model and, therefore, can become a change request for the reference model
- Impact analyses have to be made more carefully as they might affect several variants

Even if the actual process is not based on a process line, a change in the process can have serious impact. A major problem is the definition of "actual process" (Sect. 4.1.2). From a project's perspective, the actual process is the one that is instantiated in the project; from the perspective of a process engineer, the actual process is the one that reflects the current style of working in a project and, finally, from the SPM perspective the actual process might be defined as the latest published version of a process. To this end, change management in the context of SPM has to put emphasize on a change and the respective impact analyses. Furthermore, change management has to be aligned with the release management.

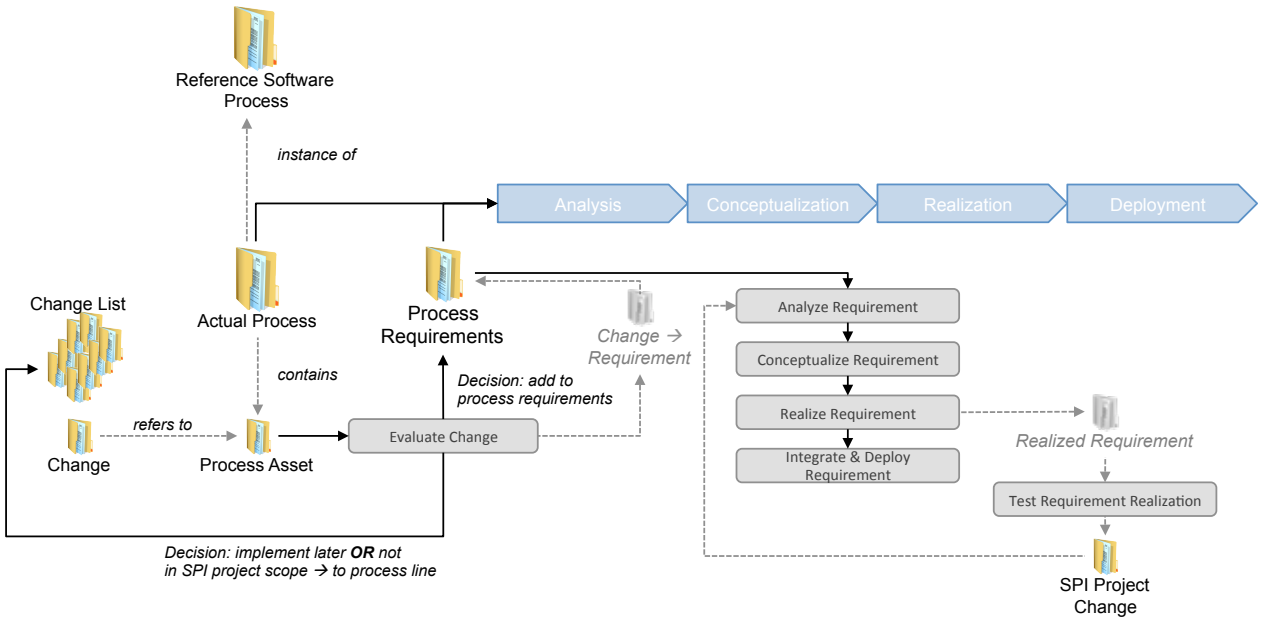


Figure 16 Change management process – SPI project perspective.

The basic (generic) change management process for SPM from a SPI project perspective is shown in Figure 16. This perspective addresses a single SPI project in which a set of changes, which refers to a set of *process assets* to be changed, is evaluated. If the decision was made to implement a change in the next iteration of an improvement project, the change is transformed into a requirement. The figure also shows the life cycle of the requirement and also shows the difference between a change from the process's life cycle and a change that occurs at project runtime (in the figure mentioned as "SPI project change"). The latter one is part of the development cycle and is usually caused by quality assurance measures, e.g. a review.

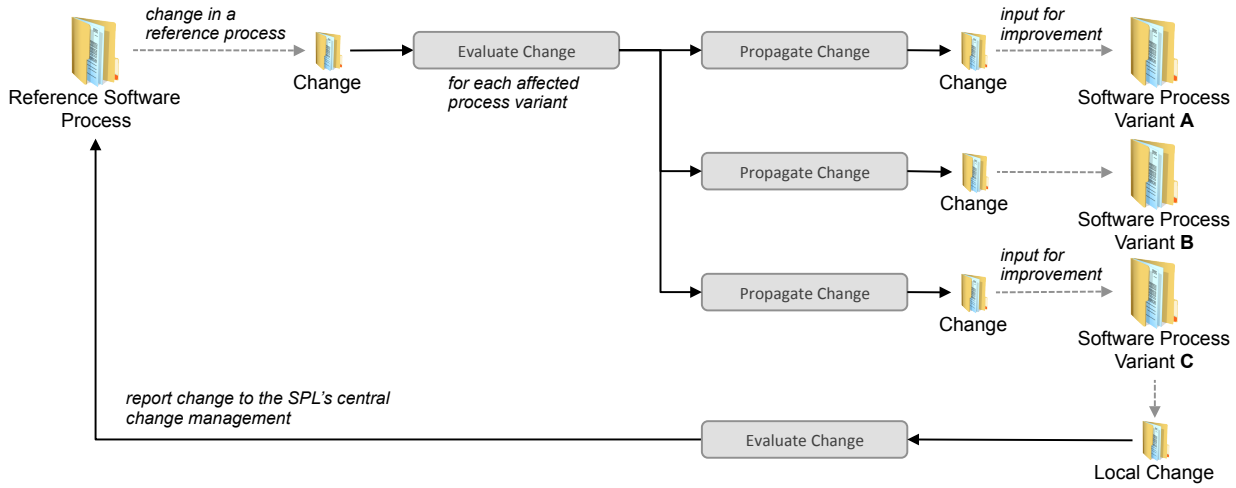


Figure 17 Change management – software process management perspective.

In Figure 16, the project-internal perspective, and the difference between life-cycle-based and project-internal changes are shown. While the internal changes are caused by development activities, the management of the software process causes the life-cycle-based changes. In Figure 17, a scenario is given in which a change is caused by a reference process. The change is evaluated and propagated to all affected process variants. The change becomes an input for the further improvement, is evaluated in the SPI project, and so on (see Figure 16).

We call a setting in which the change is "actively" propagated to dependent variants *directed evolution* – as for instance shown in the context of the V-Modell XT (Sect. 1.1; the reference process causes changes in the particular variants). The other way, if a change is raised by a variant, e.g. by defining a new best practice or an improvement, the change can also become relevant for reference process and further process variants. To this end, the change is evaluated and reported back to the central change management. We call such a setting *practice-driven improvement*.

Remark
Changes in a software process that is a variant of a software process line often cause SPI projects to analyze, design, realize, deploy, and evaluate the change. In other words: While a change on the SPI project level usually causes a task, e.g. "…implement this…", a change on the SPM level often causes a whole SPI project, e.g. "…implement support for this new RE approach…".

8.3.2.3 Release Management

Taking the example from Figure 15, the necessity of a mature release management becomes obvious. For instance, an evolution in the reference model may cause new releases for the variants as well. To start the development on a new variant, the reference model should be stabilized and released in order to build the variant on a solid basis (for instance, in the project *4* from Table 1 we experienced the "moving target" syndrome, which caused additional effort as we had to start the project twice).

The release management is responsible to state:

- Which features are new implemented in the process (methodical as well as technical)
- Which issues/feature requests are included and which remain open issues
- What is the corresponding technical backbone

The technical backbone is crucial. In our technical report [85], we investigated the V-Modell XT family and learned that each release required a specific configuration of technical components – a downward compatibility was not always given.

Regarding the features, new features in terms of determining the conformance might affect variants. Furthermore, if a variant of a process line was created using variability operations, changes in the reference model could affect the variability operations, e.g. a role was renamed in a variant and in an evolved reference model the new name was adopted then the particular variability operation is obsolete and, therefore, should be removed.

Furthermore, the release management should define what is in a particular *process release* (Sect. 0), which process assets build the process, which tools are shipped, and so on. Also, the release management should allow for identifying a release in the *roadmap* (Sect. 7.1.4).

Since the release management also depends on the technical infrastructure with which the process is authored and built, agreements are necessary to determine:

- What is part of a release?
- Is there an integrated build management (tool), and how to use it?
- Who are the players initiating the build, packaging, and deployment?
- How is the process deployed (e.g., set of HTML-pages, installer, and so forth)?
- Who is responsible to update plans and management procedures?
- How to find the right version/release/build-numbers (e.g. what is a major/minor release)?
- …

Those aspects need to be defined a) in the *project manual* and b) in the *process life cycle support* (part: deployment and further development). In the *project manual*, the basic procedures need to be defined regarding responsibilities, packaging, testing, etc. – this information is usually addressing one particular *process release*. In the *process life cycle support* documentation, all the aspects regarding deployment (in general), training, and evaluation is documented. This information is not limited to one particular *process release*. The basic (generic) release management process for SPM is shown in Figure 18.

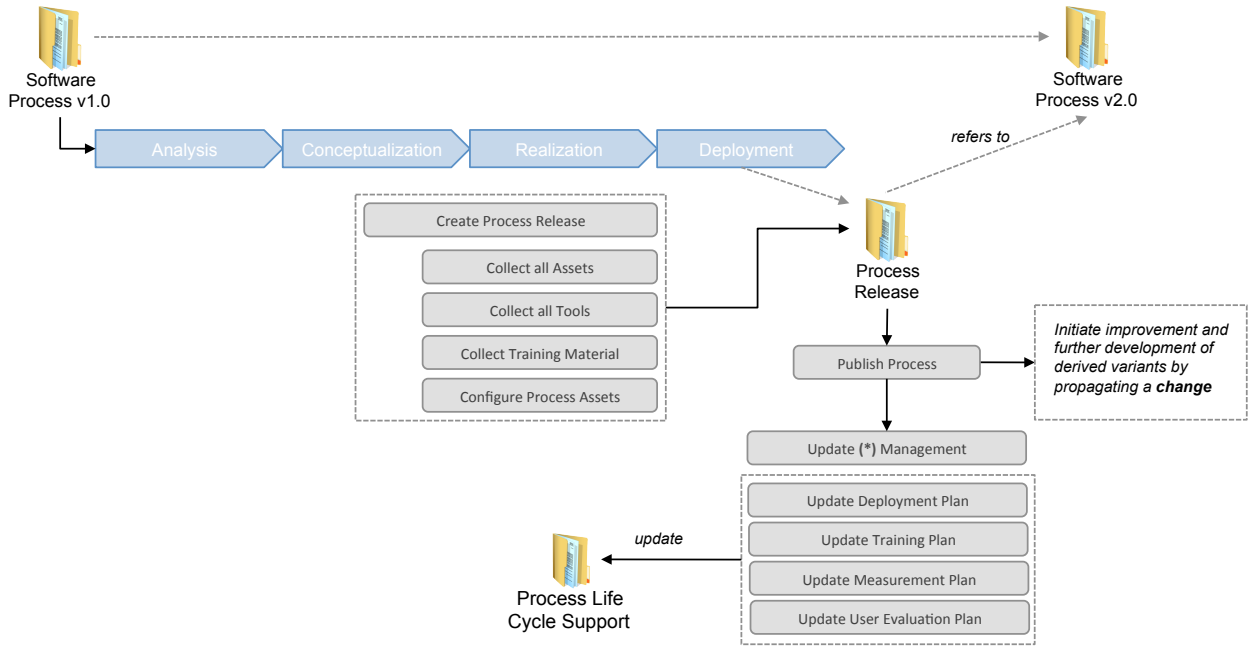


Figure 18 Release management – Condensed view

The starting point is a given software process that needs to be improved. During the SPI project *process releases* are created. To create a *process release* (see also Figure 14), all relevant *process assets*, *tools*, and *training material* have to be collected and appropriately configured. The resulting *process release* is then published (we assume that a quality assurance was successfully done before!). At this point, a new version of the process is available and (at least) one release that reflects the changes, improvements, etc.

In response to the new *process release*, at least three activities follow:

1. Update all management activities
2. Update the *process life cycle support*
3. Propagate a change and "notify" all process variants

The management activities need to be updated to include the new release, e.g. the change management process has to be extended by information regarding the new release, i.e. a new entry in the list of releases so that reporters can select the new release as reference for a problem. The life cycle support needs to be updated, as it comprises all long-term planning information and basic life cycle procedures, e.g. deployment, roadmap, training. These contents have to be updated in order to reflect the changes of the new *process release*.

Finally, all active process variants that are built based on the updated process need to be notified that there is a new process release available. The new *process release* causes a *change*, which has to be handled by the process variants (cf. Sect. 8.3.2.2; Figure 17).

Remark
Producing a *process release* is a challenging task that must not be underestimated. For instance, when planning a process release of one of our SPI projects (cf. Sec. 1.1), we (the process engineering team) have a workshop in which we have a "deployment template" on the whiteboard, which we fill with contents (e.g. which export of the documentation has to be provided, name of the requires tools, its version…), and crosscheck the respective requirements. The resulting image serves as guidance to execute the build and packaging tasks and, finally, the shipment.

8.4 Analysis and Design Decisions

Several of the aforementioned analysis and design steps depend on the particular setting of the SPI project. From our projects, we could extract some key questions that influence either the whole project or parts of it. In the following we list these questions and discuss their implications.

8.4.1 What is the purpose of the SPI project?

The first and most important question is for the project goals. The goal definition addresses basic conditions (cf. *process requirements*; Sect. 7.1.1) as well as the purpose of the SPI project. Exemplary purposes are:

- *Deployment of a standard software process*: The intention of this particular approach is to replace a proprietary process by a standardized software process. When selecting this option, special attention has to be paid to the analysis phase. Also, during the conception phase first considerations regarding the process infrastructure have to be made as the process engineering team as well as the process consumers have to get familiar with the potentially new process engineering framework and the corresponding tools. Such a replacement usually requires a fully instantiated artifact model as the whole process and its environment need to be designed.
- *Improvement of already deployed software processes*: A given process needs to be improved and, therefore, all the material that is already present in the organization needs to be identified in the analysis phase. Special attention needs to be paid on the input material, on gap analyses, and on (available) key performance indicators in order to identify the process parts to be improved (cf. assessment-related artifacts; Sect. 9.1).
- *Migration to a standard software process engineering environment*: This setting is comparable to the first setting. The difference is that the process contents are not a subject of improvement and that only the technical infrastructure needs to be reorganized (the project *4* from Table 1 is an example). Anyway, using a new infrastructure might also cause several changes in the process model and, therefore, the impacts have to be analyzed quite detailed to ensure the new process provides the same information and support as the old one. A reason for this setting is the migration in order to initiate a long-term management of the software process, e.g. the old process is documented using textbooks while the new infrastructure uses modeling tools that allow for better dealing with evolution.

The purpose directs the entire SPI project by defining the overall goal (cf. *process requirements*; Sect. 7.1.1). Each single design decision is potentially influenced by the initial goal definition.

The goal definition is complemented by certain basic conditions that also influence design decisions, the implementation approach, and so forth. Exemplary basic conditions are:

- *Typical projects*: A process should reflect the typical projects in which the process shall be applied. If the new process does not reflect the projects' demands appropriately, the process will be rejected. Furthermore, the information regarding the typical projects provides important information which tailoring criteria [39] could be of interest. This condition has impact on the tailoring model (cf. *conceptual process design* and *technical process design*).
- *Conformance requirements*: Conformance constraints provide, e.g. regulations and requirements that the considered process needs to address. Such constraints depend on the particular domain in which the process shall be applied, e.g. automotive, aerospace, or medicine. This condition has impacts on the quality assurance and process assessments that have to be planned accordingly.
- *Existing processes*: Beyond the software development, organizations usually define a number of further processes, e.g. sales, operations, and decision-making processes at the management level. Such (business or decision-making) processes need to be addressed by the considered process in order to be seamlessly embedded in the hosting organization. For instance, in the projects *3*, *4*, and *6* from Table 1 the interfaces to the organization were of special importance. Especially in the project *6* the definition of the interfaces was essential while the definition of the development process was not that challenging. This condition has impact on the *process requirements* and the *conceptual process design*.
- *Tools*: A 1,000-page process documentation is worth nothing as nobody will read the documentation in a project that has to deal with other "problems". Furthermore, developers that have to code may be more interested in a support, e.g. addressing the used work item tracking system. Another perspective is the infrastructure that process engineers use to implement the process. For instance, if a comprehensive project-

specific tailoring model is required the SPEM-based EPF environment is not meaningful. On the other hand, the V-Modell XT infrastructure is completely in German and, therefore, is limited in its international applicability. This condition has impacts on the *process requirements* and the *technical process design*.

8.4.2 Which kind of knowledge is already present in the organization?

This question aims at the existing process related knowledge of the organization driving the SPI project and *can* include a maturity level, e.g. CMMI or ISO 15504. Taking into account the existing knowledge, the whole project can be influenced, e.g. stakeholders do (not) know what it means to initiate a SPI project and, therefore, have (no) illusions about the reachable goals. From the perspective of the process engineer, the existing knowledge results in different approaches, e.g. different analysis and design approaches, different communication, or higher demands in training or project marketing (cf. *process requirements*; 7.1.1, *conceptual process design*; 7.1.2, *process life cycle support*; 7.1.4).

8.4.3 Which kind of input material is available?

Even if a software process is not explicitly documented, the normal case is that some material is always in place. The fist step is, therefore, to figure out which kind of material is available and what is the material's quality. For instance, when it comes to an improvement project, the "old" process has to be analyzed. In the projects *3* and *4* from Table 1 rich and mature material was available for analyses, reuse, and further development. In [54], we presented a student project in which the process under consideration was defined almost 10 years ago and did not reflect the actual procedures at all. Anyway, although this input material was hard to reuse it had to be analyzed to get the basic information required to talk to the client. The kind of the available input material influences the whole project as it has impact on the analysis processes and may also affect the project goals (cf. *process requirements*; 7.1.1, *conceptual process design*; 7.1.2).

8.4.4 Which development strategy shall be applied?

This is also in important question that also depends on the process framework. For instance, although the *conceptual process design* (Sect. 7.1.2) is usually created following a bottom-up approach, the V-Modell XT requires (partially) a top-down development for the realization [59]. Although the artifacts (V-Modell XT: work products) are quite early defined, for their implementation a tailoring module is required, which is a container element that is rather late defined in the definition of the tailoring model (cf. *conceptual process design*; 7.1.2, *technical process design*; 7.1.3). Another example: During our study in [54], we found several issues regarding collaborative and parallel work using SPEM (Eclipse Process Framework (EPF) environment and Subversion), which forced the process engineering teams into a sequenced work style. In the organization of the realization phase, such requirements and (known) weaknesses need to be taken into account.

To this end, the concrete approach depends on the basic decision, how the process can and shall be implemented (which also depends on the selected framework):

- *Develop a software process from scratch*: If a process shall be developed from scratch, a comprehensive planning and management is required. Each process asset has to be analyzed, designed, implemented, and tested. To this end, a fully instantiated artifact model (cf. Sect. 9.1) is required in order to address all aspects, the process engineering and, beyond, project management, quality management, release management, training, and so forth.
- *Customize a given standard software process*: Customizing a standard software process is, on the first sight, an efficient approach as it allows for reusing standardized contents. However, in the requirements phase and in the analysis phase detailed analyses have to be made to clearly define the purpose of the intended process, and to figure out how the standard process can contribute to the identified goals. To this end, process assets from the standard process that shall be reused need to be identified. Furthermore, necessary customizations need to be defined, e.g. extensions to existing artifacts, or (as a simple example) required renaming of roles or artifacts. Accordingly, the conceptualization and the realization have to address two aspects: (1) the customization of the reused process assets and (2) the design, realization, and integration of the new process assets. This condition has impacts on the *conceptual process design*.
- *Create a variant in a software process line*: The creation of a process variant, which is based on a software process line (SPL), is comparable to the customization setting. However, there are differences in the approach as the customization options a process engineer can use are usually limited by the infrastructure on

which the SPL is built. A process engineer has to figure out which operations are available and "allowed". Furthermore, SPLs usually have certain conformance constraints and, therefore, several additional artifacts, e.g. a SPL-Delta report, or several assessments (cf. Sect. 9.1) have to be created. This condition has impacts on the *conceptual process design* and on the *technical process design*.

8.4.5 Which implementation technique shall be applied?

Although this is a technical question, the implementation technique – the process engineering framework – has to be defined as soon as possible. While the *process requirements* and the *conceptual process design* can be created without paying much attention to technical or realization-related question, at latest when starting the process realization the process engineering framework has to be defined and it also has to be in place.

In an initial iteration, e.g. prototypes can be used to evaluate process engineering frameworks (Figure 13), solutions can be compared and evaluated – as exemplary done in [54] – however, at a certain point the decision has to be made as the process engineering framework has massive implications on fine-grained process designs.

Example
For instance, SPEM and the V-Modell XT have each a different notion of the importance of artifacts. Consequently, selecting either the one framework or the other limits the available design elements, e.g. SPEM does not support fine-grained artifact dependencies, and the V-Modell XT does not support fine-grained workflows.

For the refinement of the *conceptual process design* (Sect. 7.1.2) in the *technical process design* (Sect. 7.1.3), such a decision is important as the realization models highly depend on the available technical design elements. To this end, the implementation technique depends on the selected infrastructure and also influences the refinement from the *conceptual process design* to the *technical process design*. An exemplary implication is the design refinement regarding the criteria for structuring the *process assets*:

- *Emphasis on processes and activities*: This design criterion highlights the question for "what is done". Low-level activities (also single tasks) are collected, structured, and generalized. The purpose is creating some kind of workflow that links the players to the necessary activities. Artifacts are inputs and outputs of the workflows (cf. Sect. 9.4.2.3); dependencies between the artifacts are expressed by dependencies between the activities (data-flow). This approach can – on the one hand – be used to create activities based on an actual process, but also – on the other hand – to define fine-grained methods in which every single activity can be described in every detail.
- *Emphasis on artifacts*: The concentration on artifacts is a more general approach. Concrete methods are not in the spotlight. The relevant information is given by the question for "what is produced". Avoiding concrete method descriptions gives the process consumers the freedom to select their favored methods to do certain tasks – as long as the artifacts are produced in the required structure and in the required quality. The challenge is to take control of the dependency network (cf. Sect. 9.4.2.2). Since artifacts are no longer input and output for workflows, the dependencies between the artifacts need to be differently expressed, e.g. which artifact causes the creation of another one. Also, for designing and implementing a process the artifact-based approach shows some advantages, e.g. comprehensive models, ease of understanding dependencies [54].

In order to allow for a collaborative development, a long-term evolution and maintenance, and a process tailoring, criteria for structuring process assets influence the creation of reusable building block (process modules).

8.4.6 Which deployment strategy is feasible?

The deployment strategy influences many aspects of a SPI project, e.g. project planning in general, and deployment-/release management or training planning in particular. Furthermore, the deployment strategy is politically critical aspect as schedules have to be aligned and transitional arrangements have to be made. Basically, three deployment strategies can be distinguished:

- *Big Bang*: The big bang strategy sets a deadline. All new projects have *now* to use the new process. For existing processes either transitional arrangements have to be made or migration strategies have to be worked out.

- *Stepwise*: Using a stepwise migration means that not the whole process is introduced at a time, but selected sub-processes are deployed step-by-step, e.g. a new requirements engineering process or a new test process.
- *Pilot projects*: Strongly related to the stepwise process deployment, a deployment via pilot projects is another deployment strategy. In this strategy, selected projects use a new process to (1) test and evaluate the new process, and (2) to train the people and to create promoters.

All strategies bear risks and chances. For instance, the big bang strategy sets a clear deadline and, therefore, all projects know which process is the one that counts. On the other hand, potentially untrained people have to use a new process, which may increase usage mistakes or which may cause quality and scheduling problems. The stepwise deployment has the advantage that selected processes can be deployed to selected projects. The disadvantage is that the whole deployment process takes longer since all parts of the process have to be deployed step-by-step. This may also complicate the process maintenance as, for instance, feedback of already deployed sub-processes comes in and needs to be considered for "bug fixing" while other parts of the process are not yet deployed at all (Sect. 8.3.2).

An effective and proved deployment strategy is the deployment via *pilot projects* in which the new process is tested and evaluated, and awareness regarding the new process can be generated. Furthermore, pilot projects can serve as reference projects that can create initial KPIs, which can be compared to KPIs from already completed projects, and that can also build a basis for further measurement (Sect. 8.3.2.1). However, driving a pilot project is hard and most pilot projects suffer from the new process: newly introduced methods have to be learned and optimized, pilot projects bear conflict potential as they might not be "that successful" as expected (too expensive, too late). Therefore, when it comes to pilot projects:

- The "right" projects need to be defined in which the "right" people work.
- The right project is not too big and not business critical.
- The right project meets the improvement goals and allows for measurement.
- The right project can withstand evolving processes.

Using pilot projects as means to deploy a new process requires intensive communication. The management has to respect that a pilot project may be late, and that a pilot project may have quality issues. Anyway, the management has to recognize this particular situation and the process engineers should have an eye on the project flow: quality issues can occur – but their number should decrease over time. An important remark: Sometimes, there is no appropriate pilot project.

8.4.7 How to organize the training schedule?

The organization of the training is also an important aspect that affects the SPI project. Detailed discussion on this topic can be found, e.g. in [4]. In terms of our model, the organization of the trainings is relevant when creating the release plans. Training material is part of a *process release* and, therefore, part of a delivery. Furthermore, if it was decided to, e.g. create awareness by involving early adopters or the top management, training material has also be created besides the usual development and release cycles.

Same as for requirements or the process in general, training material needs to be designed, implemented, and tested. It is important to define which stakeholder groups should participate in trainings and what is the relevant content. Therefore, the planning and the design for the training material is an important task during the creation of the *conceptual process design* (Sect. 7.1.2).

Remark
Another aspect that needs to be considered when planning the trainings: Trainings are, from the perspective of a process engineer, a quick win. It is a good forum to get feedback. Also, experience shows that participants use trainings to vent their frustrations, which is a good chance for a process engineer to get further insights into weaknesses that might be overseen during the analyses.

9 Further Information

9.1 Artifact Catalog

In this appendix, all artifacts are described in detail. For each artifact, the name is given, the kind, and further information. The kind of the artifact categorizes the artifact to be a *key artifact (mandatory)*, an *external artifact*, or an artifact that is *optional*. An external artifact is given by, e.g. complementing processes such as project management. Such artifacts are required to operate a project, but do not contribute content to the process improvement.

Artifact Type	Kind	Further Information
Conceptual Process Design	K	The conceptual process design contains all designs of a process without paying attention to any technical realization. It refines all process-related requirements and transfers them into concrete processes and process parts.
Technical Process Design	K	The technical process design refines the conceptual process design w.r.t. a concrete technical implementation and the tool/tool infrastructure to be used for the process's realization.
Process Requirements	K	The process requirements contain all requirements regarding the process development.
Process	K	The process is the subject of interest. The process is the entire package that contains the process (description) itself, the corresponding tools, and additional material, e.g. training material. Since a process is a long-living entity, evolution and deployment require process releases. Each process can have multiple releases.
Deployment Plan	O	Each process, at least comprehensive ones, should have a respective deployment plan in which is documented, e.g. which releases are deployed, for whom, or which particular (sub) process have to be deployed and evaluated.
Measurement Plan	O	The measurement plan contains all information on measuring the process improvement, which includes several parameters on product, process, and project performance. A measurement plan is based on a measurement strategy in which defines metrics that are of interest for a particular SPI project.
Training Plan	O	The training plan contains all information regarding the planned trainings for the process consumers. The consumers can be: process engineers (for maintaining and further developing the process), quality managers, the company's management, and the process users (project teams).
User Evaluation Plan	O	While the measurement plan of a process aims at measuring the process performance in general, a user evaluation plan aims at evaluation the actual use of a process. In contrast to "classic" KPI-based measuring, the user evaluation is more of a qualitative nature.
Contract	E	A contract defines the basic agreements on a SPI project. The contract is either a "formal" contract or an agreement – important: the contract has at least to contain the goals, work packages (that allow for planning), and a schedule that, all together, can be used to define a development strategy, a deployment strategy, a training strategy, and so forth.
Project Plan	M	The project plan contains all required planning information of the SPI project (not of the process under development). The project plan can, depending on the concrete project configuration, contain several plans, e.g. the deployment plan, the quality assurance plan.
Training Material	O	Training material consists of material to train the process consumers. The training material is specific for certain user groups/stakeholders and for particular releases. Usually, training material is explicitly defined for the stakeholder groups and, therefore, provides different perspectives and information on different levels of abstraction.

Artifact Type	Kind	Further Information
Assistance Tools	O	Depending on the concrete process, assistance tools have to be defined, packaged, and delivered with a process. Assistance tools can be: generators, viewers, and so forth.
Process Release	K	A process release is a concrete process package that is shipped and deployed.
Process Life Cycle Support	K	The process life cycle support comprehends all information, agreements, and definition regarding complementing processes that support the deployment, training, and further development of a concrete process. The life cycle support comprehends at least agreements for: training, deployment and further development, measurement and evaluation, and change management. Depending on the concrete project setting, the life cycle support can also be integrated with other artifacts. However, when a large and comprehensive process is developed/improved the life cycle support should be explicitly defined.
Metric Catalog	O	The metric catalog contains all metrics considered relevant for a particular SPI project.
Process Assessment	O	A process assessment evaluates a particular software process regarding, e.g. maturity, gaps, capabilities. An assessment can be an input for the process requirements or an outcome in the process's evaluation (if defined in the measurement plan).
Conformity Assessment Report	O	If a process is developed in an environment that requires evidence regarding certain properties, e.g. safety, conformity to a reference model could be of interest.
SPL-Delta Report	O	If the considered process is based on a software process line, a delta report is helpful to analyze deviations from the SPL base process to support long-term development (having the SPL's evolution) in mind.
Software Process Line	O	A software process line is a…
Process Metamodel	O	A process metamodel (a software process metamodel) is a (formal) language in which software processes are described. A process metamodel serves the construction of a software process and its automation.
Process Tools	O	Process tools support the process engineers and users, and provide access to a process. Process tools are at least authoring tools and assistance tools. Depending on the considered process and its basic technology, process tools can also comprehend build tools, change management tools, or configuration management tools.
Test Specification	O	A test specification contains all test criteria for a quality assurance procedure.
Test Protocol	O	A test protocol documents an executed test procedure and its results.
QA Report	O	The QA report (quality assurance report) summarizes the current project status of the SPI project summarizing all outcomes of the quality assurance. Depending on the particular setting, the QA report can also contain other, but related, information, e.g. user evaluations, tentative assessments.
Quality Assurance Plan	M	The quality assurance plan contains all scheduled information regarding the planned (and staffed) QA measures.
Quality Assurance Manual	M	The quality assurance manual is the "connection" to the company's quality management. It summarizes all quality goals that are relevant for a project. Furthermore, all artifacts are listed that are subject to quality assurance, which measures are adequate, and what are the concrete quality goals.
Supporting Material	O	Each software process contains material going beyond the plain process description, e.g. training material, document templates.

9.2 Tailoring the Artifact Model

Since SPI projects can have a different organizational context, different size, different purpose, and different objectives, not all of the aforementioned artifacts are necessary in every SPI project. However, the introduced artifact model reflects all requirements regarding the outcomes of an SPI project and, therefore, should be present in a SPI project. Although being relevant, the representation of the artifacts is not "that" important, and it is also not necessary to create each artifact as a self-contained document.

9.2.1 The Process Design

In order to support smaller as well as bigger SPI projects, the artifact model supports certain tailoring options. The most important one is the merge of the two comprehensive design artifacts: the *conceptual process design* (Sect. 7.1.2) and the *technical process design* (Sect. 7.1.3).

The resulting artifact – the *Process Design* – is a "reduced" artifact that comprises the essential parts of both design artifacts. The *process design* was used in the projects *3* and *6* from Table 1 in order to reduce the documentation effort (and also the maintenance effort for the design documents).

In which situation, both artifacts should be merged?

The artifacts should be merged in projects in which only small processes are developed or in that only sub-processes are the subjects. For instance, in project *6* a (relative) small method development process was designed, and the focus was on the embedding of the process into the organization. To this end, the *process design* contains only small pieces of artifacts and process parts; but the emphasize lays on the organization and role model, which is designed in every detail.

How to check that nothing important was forgotten?

The merge always bears the risk that important aspects are forgotten. To aid this situation, it is recommended to use the checklist from Sect. 9.3. Using this checklist, every artifact and sub-artifact, which each represent relevant contents (and activities), can be analyzed for:

- Relevance in the project
- Creation and creation kind

Using the *process design* means that sub-artifacts from the *conceptual process design* and from the *technical process design* are usually mapped to the corresponding "chapters" of the integrated *process design*. In the checklist, every artifact can be labeled to be relevant or not, and if a particular sub-artifact was considered relevant, the checklist can be used again to check whether the required contents are realized in a project.

How does the Process Design look like?

In the following mapping table, the mapping of the *conceptual process design* and the *technical process design* to the merged *process design* is given:

Process Design	Goals & Principles	Organization and Role Model	Artifact Model	Process Model	Process Documentation	Supporting Material	Tailoring	Technical Aspects	Requirements Tracing
Conceptual Process Design									
Goals	X								
Principles	X								
Planned Adaptations									
Organization and Role Model		X							
New Roles									
Customized Roles									
Removed Roles									
Grouping and Categorization									
Artifact Model			X						
New Artifacts									
Customized Artifacts									
Removed Artifacts									
Artifact Dependencies									
Artifact to Artifact Dependencies									
Artifact to Role Dependencies									
Artifact to Process Part Dependencies									
Process Model				X					
New Process Parts									
Customized Process Parts									
Removed Process Parts									
Overall Process									
Bird’s Eyes Perspective									
Milestones									
Milestone to Artifact Dependencies									
Milestone to Process Part Dependencies									
Role to Process Part Dependencies									
Process Documentation Model					X				
New Documentation									

Process Design	Goals & Principles	Organization and Role Model	Artifact Model	Process Model	Process Documentation	Supporting Material	Tailoring	Technical Aspects	Requirements Tracing
Customized Documentation									
Removed Documentation									
Supporting Material Model						X			
New Supporting Material									
Customized Supporting Material									
Removed Supporting Material									
Tailoring Model							X		
Requirements Tracing									X
Technical Process Design									
Logical and Physical Model Organization								X	
Metamodel Adaptations									
Variability Operations									
Organization and Role Model Realization		X							
Integrated Organization Model									
Integrated Role Model									
Artifact Model Realization			X						
Integrated Artifact Model									
Process Model Realization				X					
Integrated Process Model									
Process Documentation Model Realization					X				
Supporting Material Model Realization						X			
Tailoring Model Realization							X		
Tailoring Modules									
Tailoring Configurations									

9.2.2 The Plans

Our artifact model names different plans:

- Project Plan
- Quality Assurance Plan (QA Plan)
- Training Plan
- Deployment Plan
- Measurement Plan
- User Evaluation Plan

The plans address different context. The project plan and the QA plan are plans that are created specific for one SPI project. All the other plans are deliverables that are created in the SPI project, and that are handed to the organization after closing the project. To give the opportunity to reduce the number of artifacts, the following merges are possible:

	Project Plan	Quality Assurance Plan	Training Plan	Deployment Plan	Measurement Plan	User Evaluation Plan
Integrated Project Plan	X	X				
Integrated Process Life Cycle Plan			X	X	X	X

The project plan and the QA plan can be integrated as long as it is ensured that quality assurance is not done "by the way". The other plans, which address the process life cycle, can be easily integrated into an *integrated process life cycle plan* – but attention: depending on the size and the estimated life time of a process, separate plans are advantageous.

9.2.3 Tailoring Profiles

Based on our experiences and the previously discussed tailoring options, we can define the following basic tailoring profiles (a more fine-grained tailoring is also possible based on the decisions which artifacts to create and which not). The proposed tailoring profiles are based on the projects (Sect. 1.1), on the key artifacts of our model, and on the previously discussed merge options. Table 17 shows the basic tailoring profiles. If an artifact is labeled "X (opt.)" both artifact materializations (self-contained artifacts as well as merged artifacts) are possible, depending on the project setting

Table 17 Basic tailoring profiles for the artifact model.

Artifact	Sect.	Profile 1 – Small	Profile 2 – Medium	Profile 3 – Large/SPL
Setting		A small SPI project or a project that aims at improving one sub-process, e.g. project 6.	A SPI project aiming at improving a whole process, e.g. projects 2, 3, or 4.	A large scale SPI project or SPL-based projects with multiple variants, e.g. project 1.
Project Manual	7.2.2	X	X	X
QA Manual	7.2.1	X	X	X
Project Plan	7.2.2	--	--	X
QA Plan	7.2.1	--	--	X
Integrated Project Plan	0	X	X	--
Training Plan	7.1.4	--	X	X
Deployment Plan	7.1.4	--	X	X
Measurement Plan	7.1.4	--	X	X
User Evaluation Plan	7.1.4	--	X	X
Integrated Process Life Cycle Plan	0	X	X (opt.)	--
Process Requirements	7.1.1	X	X	X
Conceptual Process Design	7.1.2	--	X	X
Technical Process Design	7.1.3	--	X	X
Process Design	9.2.1	X	X (opt.)	--
Process Life Cycle Support	7.1.4	X	X	X
Process Release	0	X	X	X

9.2.4 The Remaining Artifacts

The previous discussion about tailoring option and artifacts that can be merged in order to also address smaller projects is focused on the key artifacts. All other artifacts in the proposed artifact model are optional artifacts that are either created on the basis of project management decisions, the project context, or dependencies that cause the artifacts' creation. Since all the remaining artifacts are *optional*, no further explicit tailoring rules need to be defined.

9.3 Quality Assessment & Checklists

In the following a template for a checklist is given that supports process engineers in determining the completeness of the artifact model's instantiation. The checklist aids two activities:

1. Planning of the artifact instantiation/creation process
2. Completeness check

Only few artifacts are mandatory. Those are marked with "Yes" in the column *Relevant in the Project*. If an artifact is marked with "Yes*", the artifact is mandatory but can be subject to a tailoring and an artifact merge. In the column *QA* the selection of artifacts for the quality assurance can be made ("Y" = yes, "N" = no). All artifacts that are labeled with "Y" have to be listed in the *QA manual* and have to be assigned to certain QA

methods and activities. The column *Artifact Kind* contains the information, how a particular artifact is represented in the project. Finally, the column *Already Created* contains information, whether an artifact is already created (and quality assured).

For the planning process, the process engineer has to fill out the table. For the analysis, the process engineer takes the initially filled table and checks each point. This can be done in the quality assurance of the current project, but also as an initial "quick assessment" to determine which material is in place when starting a project (cf. Sect. 8.4.3).

Artifact/Sub-Artifact	Relevant in this Project?	Artifact Kind	Already Created	QA
Project Manual	Yes			Y
Quality Assurance Manual (QA Manual)	Yes			Y
Project Plan	Yes			Y
Quality Assurance Plan	Yes			Y
Process Requirements	Yes			Y
Goals				
Stakeholder and Roles				
Requirements				
Overall Process Draft				
Technical Infrastructure				
Basic Conditions				
Conceptual Process Design	Yes*			Y
Goals				
Principles				
Planned Adaptations				
Organization and Role Model				
New Roles				
Customized Roles				
Removed Roles				
Grouping and Categorization				
Artifact Model				
New Artifacts				
Customized Artifacts				
Removed Artifacts				
Artifact Dependencies				
Artifact to Artifact Dependencies				
Artifact to Role Dependencies				
Artifact to Process Part Dependencies				
Process Model				
New Process Parts				
Customized Process Parts				
Removed Process Parts				

Artifact/Sub-Artifact	Relevant in this Project?	Artifact Kind	Already Created	QA
Overall Process				
Bird's Eyes Perspective				
Milestones				
Milestone to Artifact Dependencies				
Milestone to Process Part Dependencies				
Role to Process Part Dependencies				
Process Documentation Model				
New Documentation				
Customized Documentation				
Removed Documentation				
Supporting Material Model				
New Supporting Material				
Customized Supporting Material				
Removed Supporting Material				
Tailoring Model				
Requirements Tracing				
Technical Process Design	Yes*			Y
Logical and Physical Model Organization				
Metamodel Adaptations				
Variability Operations				
Organization and Role Model Realization				
Integrated Organization Model				
Integrated Role Model				
Artifact Model Realization				
Integrated Artifact Model				
Process Model Realization				
Integrated Process Model				
Process Documentation Model Realization				
Supporting Material Model Realization				
Tailoring Model Realization				
Tailoring Modules				
Tailoring Configurations				
Process Life Cycle Support	Yes			Y
Training				
Training Concept				
(related Plan) *Training Plan*				
Deployment and Further Development				
Deployment Strategy				

Artifact/Sub-Artifact				Relevant in this Project?	Artifact Kind	Already Created	QA
			(related Plan) *Deployment Plan*				
		Roadmap					
	Change Management						
	Measurement and Evaluation						
		Measurement and Evaluation Strategy					
			(related Plan) *Measurement Plan*				
			(related Plan) *User Evaluation Plan*				
Process Release				Yes			Y

9.4 Artifact Representation and Data Formats

Depending on the concrete setting, the artifacts described in the presented model can be represented in different shapes, e.g. as documents, forms, or an electronic representation. In this appendix, we give information on the different representations and give some hints and best practices.

9.4.1 Artifact Representation

In this section, we discuss possible kinds of artifact materializations. Since we define an UML-based artifact model in Sect. 4.2, for a particular SPI project these artifacts need concrete representations, e.g. as documents. However, a document is not always the best solution for the specific context. In the following, we give an overview over possible materializations of the key artifacts and briefly discuss them. Note, regardless of the concrete materialization further artifacts are created, e.g. forms that define artifacts, sheets that contain role descriptions and responsibility assignments, and so forth. To this end, all artifacts to be created in a SPI project should be subject to configuration management and version control.

Table 18 Overview over possible key artifact materializations

Artifact Type	Possible materialization
Process Requirements	Possible materializations: • Requirements Engineering tool data set • Document • PowerPoint presentation The classic representations are the tool-based data set and the document style (also taken into account that RE tools usually can export documents). This kind of representation allows for versioning and collaborative work. An alternative, especially for small and medium processes is the PowerPoint-style as it allows for presentation and discussion. In all our projects, we used the document style and the PowerPoint style.
Conceptual Process Design	Possible materializations: • Document • PowerPoint presentation • Wiki-based system The conceptual process design is classically represented by a document, which is subject to quality assurance and shipment to the client. If the conceptual design is not that complex, a PowerPoint presentation also fits the needs, whereby more effort is spent in the creation of the technical process design. In such cases, the PowerPoint style is used mainly for communication and discussion purposes. We haven't implemented it ourselves, but several companies with which we cooperated used Wiki-based systems to describe their processes, and also use them to discuss potential improvements (which basically meets the purpose of the conceptual process design). If such an infrastructure is available, a Wiki-based system could provide befits as it allows for, e.g. hypertext references to affected process assets.

Artifact Type	Possible materialization
Technical Process Design	Possible materializations: • Document • Wiki-based system The technical process design can be materialized similar to the conceptual process design (also with the same argumentation). Only the PowerPoint-based approach seems not to be feasible and was never requested. Anyway, in most of our projects the document style was used as the technical process design was defined as a deliverable. Although it requires effort and discipline always to have the design documents in a consistent and up to date status, clients preferred a “real” physical deliverable that they can review and judge.
Process Life Cycle Support	Possible materializations: • Document • Wiki-based system The process life cycle support documentation comprehends further sub-artifacts, which themselves can reach a certain complexity. Therefore, the document style is possible (e.g. as operations handbook), but the Wiki-based approach is promising. Until now, the usual way of delivering the life cycle support documentation was in the document style (mainly for the same reason as for the technical process design).

For all other artifacts being created in a SPI project holds: Use a format that fits the current needs, e.g. the change management artifacts can be represented as single documents, items in a spreadsheet application, or items in a bug tracking system. The bigger the process and the more people are involved – developers as well as consumers – the more efficient is a comprehensive tool support. For instance, while in medium projects *2* to *5* Excel serves as change management tool the development of the reference process *1-RM* of the process line uses a fully-fledged work item tracking system.

9.4.2 Recommended Data Structures

In this section, we provide the basic data structures used for the analysis of roles, artifacts, and activities. The presented data structures aim at providing a raw data format that contains the minimal required information for the single process assets. The data points that are collected during the analysis are the starting point from which the grouping and clustering activities are started.

Remark
The data structures presented here are based on our experiences. We practically applied these structures in a document form-based fashion as well as in spreadsheet-based list styles, e.g. [54]. The concrete materialization of these analysis artifacts does not matter – important is the availability of the information collected with those sheets.

9.4.2.1 Roles

Table 19 Proposed minimal data structure for roles

Criteria	Description
No./Code	Unique identifier
Role Name	Title or name of the role
Description	General description of the role, e.g. in prosaic text
Tasks	General description of the tasks the role has to carry out
Capabilities/ Qualification	List of capabilities and required qualifications the person that has the role must have
Staffing	Description of conditions to pay attention to when assigning the role to a person, e.g. how many persons should have the role, which persons
Responsibilities	For which activities or artifacts is the role responsible?
Contributions	To which activities or artifacts does the role contribute?
Limitations	Limitations to be considered in the context of the role, e.g. other roles that cannot staffed with a person having this role.

9.4.2.2 Artifacts

Table 20 Proposed minimal data structure for artifacts

Criteria	Description
No./Code	Unique identifier
Artifact Name	Title or name of the artifact
Description	General description of the artifact, e.g. in prosaic text
Structure	Structure of the artifact, e.g. if the artifact is a composite one, or if the artifact is a comprehensive document then the fine-grained structure should be described here, i.e. using an outline
Template?	Shall a template provided for the artifact (Yes/No) – if yes, which kind of template?
When?	At what point in the project shall the artifact be ready/created, e.g. name the respective milestones
Number	How many exemplars of the artifact exist in a project, e.g. exactly 1, 1 to many, 0 to many
Responsible	Which role is responsible for the artifact's creation?
Contributing	Which roles contribute to the artifact's creation?
Dependencies	Which dependencies between this artifact and other artifacts exist?

Hint
Separate the artifact details from the dependency models. Artifact models can become quite comprehensive and, therefore, the detailed data should be separated from a self-contained dependency model. For the dependency information as required here, just name the related artifacts and indicate the type of the dependencies, e.g. content-related.

9.4.2.3 Activities

Table 21 Proposed minimal data structure for activities

Criteria	Description
No./Code	Unique identifier
Activity Name	Title or name of the activity
Description	General description of the activity, e.g. in prosaic text
Structure	Structure of the activity, e.g. if the activity is a composite one the fine-grained structure should be described here, i.e. using an activity model or a workflow?
Input artifacts	Which artifacts are required as input to carry out the activity?
Output artifacts	Which artifacts are produced as output of the activity?
Number	How often is the activity executed in a project, e.g. exactly 1, 1 to many, 0 to many
Responsible	Which role is responsible worker for the activity?
Contributing	Which roles contribute work to the activity?
Dependencies	Which dependencies between this activity and other activities exist?

Hint
Separate the activity details from the dependency models. Use an activity-based modeling technique to create (hierarchical) activity models, e.g. using the UML, and put them into self-contained models.

10 Glossary

CPD	Conceptual process design; Sect. 7.1.2
CMMI	Capability Maturity Model Integration
ISO 15504	(aka SPICE) – Software Process Improvement and Capability Determination
Process-engineering framework	(short: process framework) – According to [56] “a combination of SPMMs, tools, and guidelines” that form the framework in which a software process is analyzed, designed, implemented, and deployed.
PLC	Process life cycle support; Sect. 7.1.4
PM	Project management
PR	Process release; Sect. 0
PRQ	Process requirements; Sect. 7.1.1
SPI	Software process improvement
SPL	Software process line
SPLC	Software process life cycle model; Sect. 8.1
SPM	Software process management
SPMM	Software process metamodel, e.g. SPEM, V-Modell XT
TPD	Technical process design; Sect. 7.1.3
QA	Quality assurance – part of QM, which is instantiated and done in a project context.
QM	Quality management
V-Modell XT	The German standard IT development process; available online: http://www.v-modell-xt.de (English version available)

11 The ArSPI Model

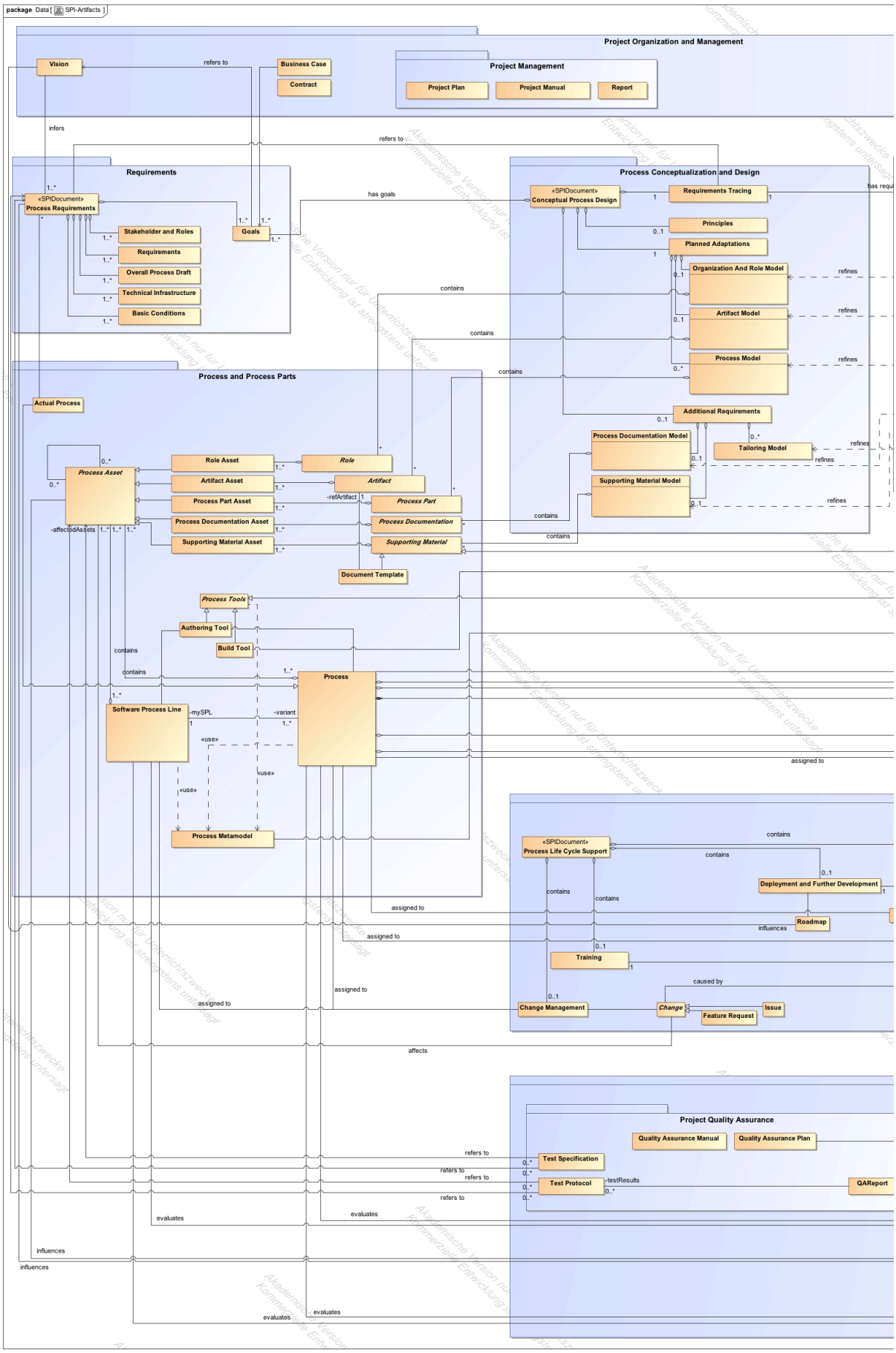
In the following, we present the complete ArSPI model in its UML representation. All model pictures can be downloaded at:

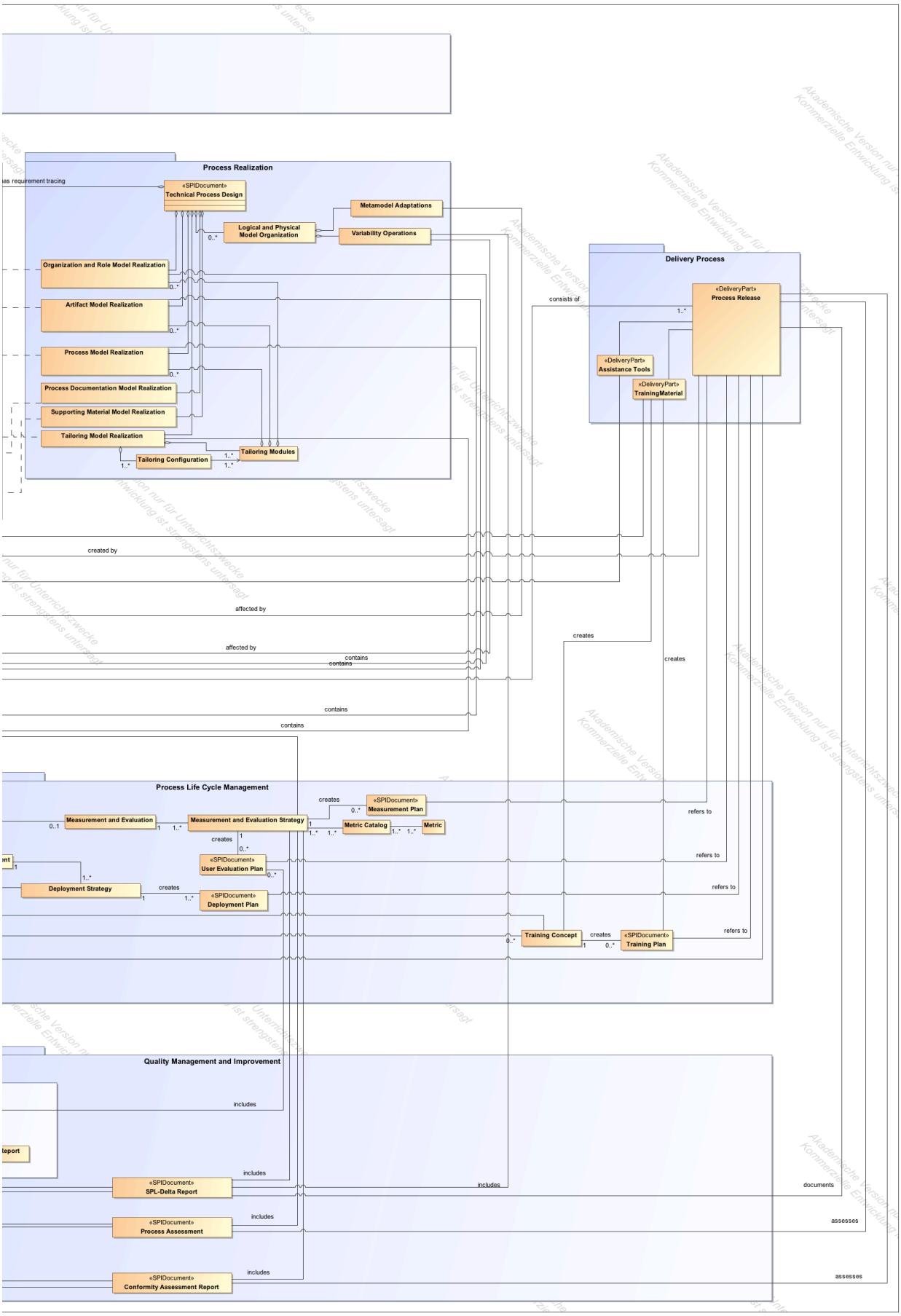
http://www4.in.tum.de/~kuhrmann

In the following, we present the overall model, and the key elements and their relation:

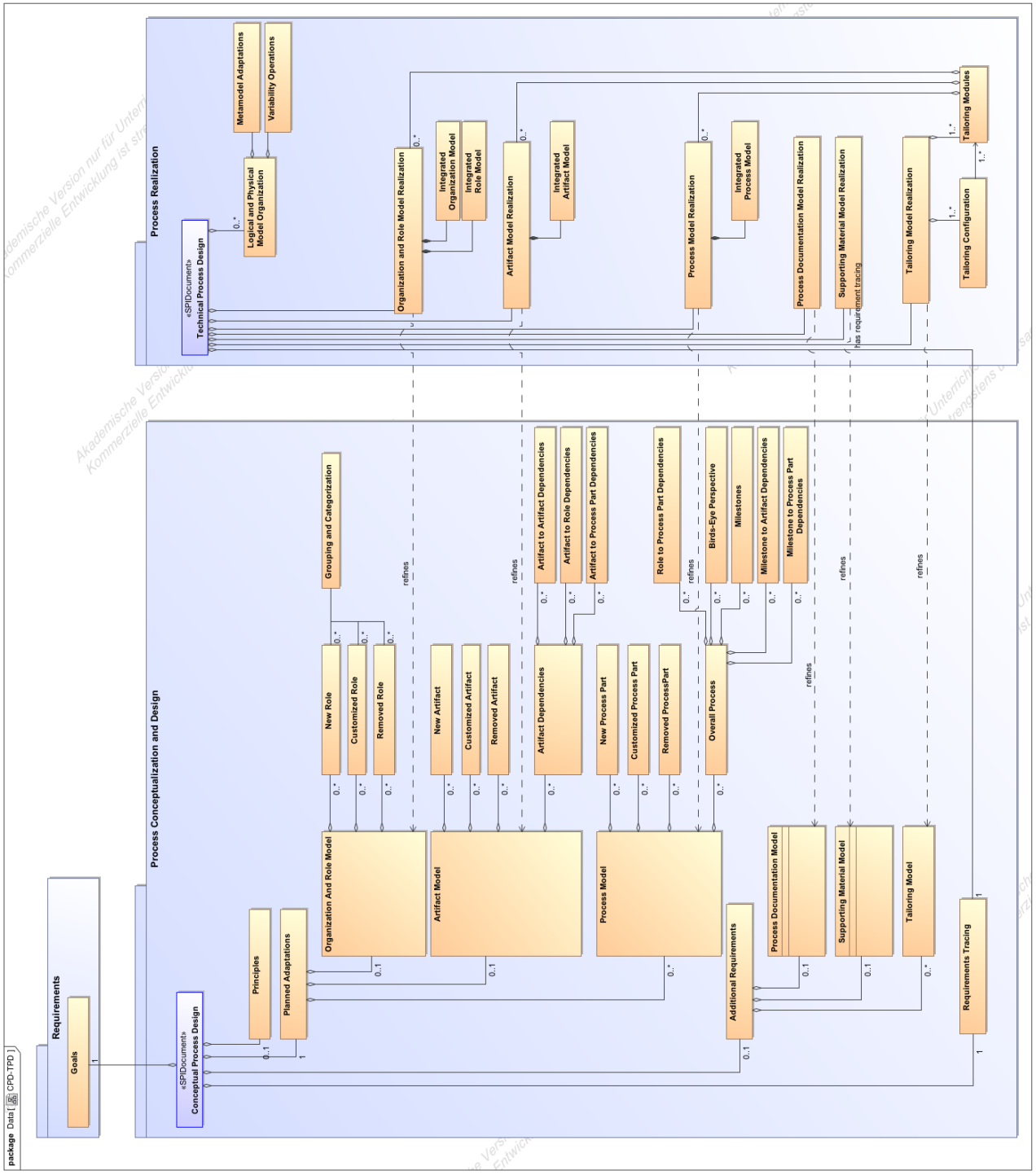
- The overall model
- The relation between the conceptual process design and the technical process design
- The relation between the process assets and the conceptual process design
- The relation between the process assets and the technical process design

11.1 The Overall Model

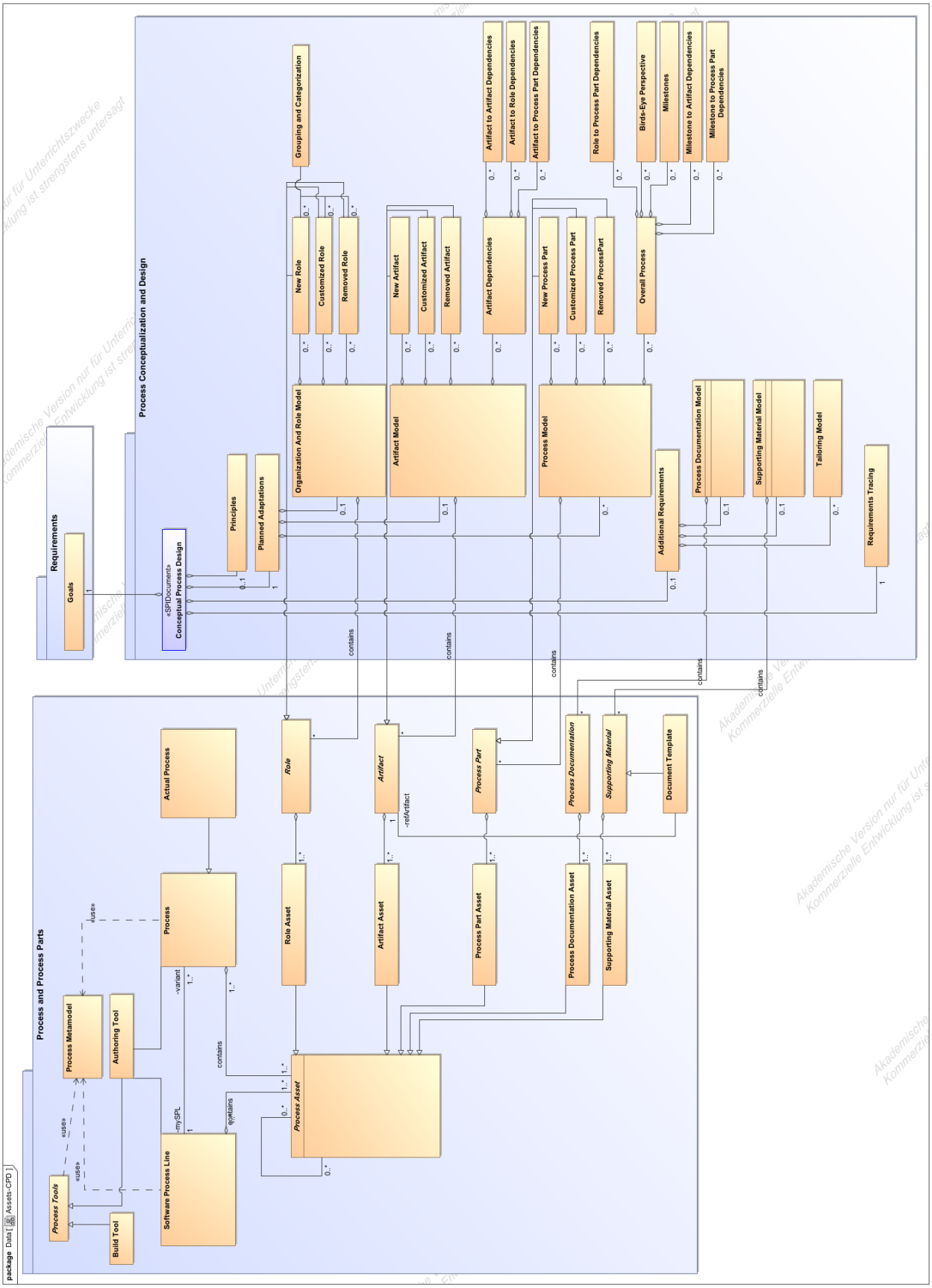

package Data [SPI-Artifacts]
Project Organization and Management
Vision
refers to
Business Case
Contract
Project Management
Project Plan
Project Manual
Report
infers
refers to
Requirements
«SPIDocument»
Process Requirements
Stakeholder and Roles
Goals
Requirements
Overall Process Draft
Technical Infrastructure
Basic Conditions
has goals
Process Conceptualization and Design
«SPIDocument»
Conceptual Process Design
Requirements Tracing
Principles
Planned Adaptations
Organization And Role Model
Artifact Model
Process Model
Additional Requirements
Process Documentation Model
Tailoring Model
Supporting Material Model
refines
contains
Process and Process Parts
Actual Process
Process Asset
Role Asset
Artifact Asset
Process Part Asset
Process Documentation Asset
Supporting Material Asset
Role
Artifact
Process Part
Process Documentation
Supporting Material
-refArtifact
-affectedAssets
Document Template
Process Tools
Authoring Tool
Build Tool
Process
Software Process Line
-mySPL
-variant
«use»
Process Metamodel
assigned to
«SPIDocument»
Process Life Cycle Support
Deployment and Further Development
Roadmap
influences
Training
caused by
Change Management
Change
Issue
Feature Request
affects
Project Quality Assurance
Quality Assurance Manual
Quality Assurance Plan
Test Specification
Test Protocol
-testResults
QAReport
refers to
evaluates
influences


Process Realization
as requirement tracing
«SPIDocument»
Technical Process Design
Metamodel Adaptations
Logical and Physical Model Organization
Variability Operations
Organization and Role Model Realization
Artifact Model Realization
Process Model Realization
Process Documentation Model Realization
Supporting Material Model Realization
Tailoring Model Realization
Tailoring Configuration
Tailoring Modules
Delivery Process
«DeliveryPart»
Process Release
«DeliveryPart»
Assistance Tools
«DeliveryPart»
TrainingMaterial
consists of
created by
affected by
affected by
contains
contains
contains
contains
creates
creates
Process Life Cycle Management
Measurement and Evaluation
Measurement and Evaluation Strategy
«SPIDocument»
Measurement Plan
Metric Catalog
Metric
«SPIDocument»
User Evaluation Plan
Deployment Strategy
«SPIDocument»
Deployment Plan
Training Concept
«SPIDocument»
Training Plan
creates
refers to
refers to
refers to
refers to
Quality Management and Improvement
includes
includes
includes
includes
includes
«SPIDocument»
SPL-Delta Report
«SPIDocument»
Process Assessment
«SPIDocument»
Conformity Assessment Report
documents
assesses
assesses

11.2 Relation: Conceptual and Technical Process Design



11.3 Relation Process Asstes and Conceptual Process Design



11.4 Relation Process Assets and Technical Process Design