# CASFIS—Approach for studying software product families in industry

Mikko Raatikainen, Tomi Männistö, and Timo Soininen

Software Business and Engineering Institute (SoberIT)
Helsinki University of Technology
P.O. Box 9210, FIN-02015 HUT, Finland
{Mikko.Raatikainen, Tomi.Mannisto, Timo.Soininen}@hut.fi

**Abstract.** Software product families (SPF) are becoming more commonplace in many industrial organizations due to the increasing variability requirements. One major challenge with SPFs is to understand the challenges companies are facing as well as solutions they have tried out. Feasible tools for gathering such knowledge are qualitative research methods that include the case study method. In this paper, we propose a study framework for SPFs called CASFIS. CASFIS builds on top of case study methodology and existing work and understanding on SPFs with the aim of being a solid framework for investigating industrial SPFs. CASFIS has been tested and tried out in several industrial companies and adjusted accordingly.

## 1 Introduction

A software product family (SPF) is typically understood to roughly consist of common assets that are specifically developed for the SPF and then shared and reused in the development of the product individuals in the SPF [1] [2] [3]. The concept of a SPF has existed for decades [4], but only recently research results have shown that a SPF may provide industrially relevant benefits, such as decreased development effort and time-to-market [5] [6] and that a SPF itself and some of the issues it addresses are important and predictive for success of reuse [7] [8] [9]. Examples of the success with reuse within SPFs concern various kinds of assets, such as software architecture, instead of only code [3]. Furthermore, reuse is planned and supported instead of opportunistically assumed reuse just happen [2], and reuse is not assumed to be solely a technical problem, but to also concern other issues, such as the business, process, organizational, and architecture (BAPO) concerns [10]. Another important aspect of a SPF in addition to reuse is systematic variability management. Many of the results and issues of SPFs originate from industrial experience including case studies in companies, such as Securitas and Axis [11], CelsiusTech [12] and experience reports in companies, such as Philips [13] and Nokia [14].

In addition to SPFs gaining popularity among researchers, recently, on the one hand, a need for rigorous research methods in software engineering is identified and, on the other hand, software engineering research is required to focus on practical solutions for real problems in the industry [15] [16] [17]. One class of such methods is qualitative methods, which include qualitative case study method. Such qualitative methods

are particularly applicable to acquired data of complex real life phenomena [18]. In particular, for case studies exists rigorous methodology [19].

In this paper we propose a framework, called CASFIS (**CA**se **S**tudy **F**ramework for **I**ndustrial **S**PFs), for empirically studying SPFs in the industry using qualitative methods. On the one hand, this forms one piece in a methodological toolbox of scientific approaches that can be used to study SPFs. On the other hand, CASFIS is an attempt to form a solid basis for further discussion and development of methodologies for studying SPF. CASFIS is a revisited version of the framework [20] that was used in a case study of the state of the practice of SPFs which some results are published in [21] [22]. CASFIS contains guidelines to carry out a case study of a SPF in a company. CASFIS is defined to be used within the context of SPFs by combining our experience of scientific qualitative methods and case study methodology in particular with our experience with SPFs. Similarly as, for example, the evaluation framework [23], CASFIS follows division to business, artifact, process and organization (BAPO) concerns introduced in [10]. The focus is on SPF practices and implications that a SPF has on practices rather than software engineering practices in general. Especially the focus is on the artifacts of a SPF and their variability.

CASFIS differs from the existing frameworks such as the evaluation framework [23] and the SPF probe [3], and actual case studies by describing in detail the guidelines for the research process and as another central element the explicit case study questions. These guidelines are described in this paper. The questions are published separately in [24]. Few examples of the questions are as Appendix. Closely related and complement to CASFIS is the software product line questionnaire [6] that is a survey instrument although it consists of mainly the questions.

The rest of the paper is organized as follows. In Section 2 we describe CASFIS. Use of CASFIS is discussed in Section 3. Evaluation of CASFIS is discussed in Section 4. Related work is outlined in Section 5. In Section 6 conclusions are drawn.

## 2 Case study framework for industrial SPFs

In this section we present CASFIS. The framework follows a qualitative case study strategy [25] [19]. We use the steps introduced in [19] to describe the framework. Theses steps are *designing case study*, *preparing data collection*, *collecting evidence*, *analyzing the evidence*, and *composing a case study report*. The structure of this section is summarized in Table 1. In Section 3, rationale for the design decision behind CASFIS and guidelines for its usage are given following the same structure.

### 2.1 Designing a study

**Problem formulating.** The objectives of a study using CASFIS are to characterize a SPF in a company. The aim is to capture a rich holistic qualitative descriptive account of the SPF. This descriptive account should give understanding of all relevant aspects of a SPF in the company focusing on artefacts in a SPF particularly. This focus because a SPF a technical concept for reuse although other concerns are taken account as well [1]. This, although business is argued to be the most influential concern for a company

**Table 1.** Outline of Study Framework

| **Designing a study (2.1, 3.1)** | **Preparing data collection (2.2, 3.2)** | **Collecting evidence (2.3, 3.3)** | **Analysis and reporting (2.4, 3.4)** |
|---|---|---|---|
| – Problem formulation<br>– Study proposition<br>– Case selection<br>– Unit of analysis | – Field procedures<br>– Case study questions | – Interviews<br>– Case study database | (CASFIS does not suggest or require any particular analysis approach) |

[23]. Consequently, CASFIS can be used to answer, in short, to the research question: "what kind of SPF a company develops?"

**Study propositions.** To direct investigators' attention and to gain a preliminary understanding of SPFs CASFIS includes *study propositions*. That is, the study propositions state the assumptions that are made before a study of the nature of a SPF. These study propositions are based on a synthesis of a literature study of the reported research results on SPFs. The propositions are as follows:

A software product family (SPF) consists of a set of product individuals [3]. These product individuals share a common, managed set of features and predicted variability that are used when developing such a family [1]. A SPF includes multiple simultaneous variants of marketable products individuals, instead of only being releases and versions of a single product [3]. The commonalities of product individuals in a SPF are utilized by reusing the shared assets when developing the product individuals [1]. The shared assets and the software product family architecture are scoped and developed for reuse in a *development process* and reused to build products in a prescribed way in a *derivation process* [1], [3].

This two tiered development is usually regarded as the fundamental characteristics of all successful SPFs [26][1]. Reuse does not focus on a few isolated asset, but relatively large parts of products individuals are based on the reused assets. The assets include software components, but many other kinds of assets such as test plans and cases as well [3]. SPF architecture is a central asset and all product individuals in a SPF use the SPF architecture. Much of these shared assets have been typically developed within the same development organization [2] although, for example, COTS can be used as well [27].

**Selecting cases.** Selecting a SPF for a study using CASFIS follows *theoretical sampling* [25]. Theoretical sampling means that the SPFs for the study are selected based on some other criteria then randomly. The selected SPFs, for example, can exhibit a special characteristic or be developed using special technique. However, all cases should have a SPF as stated in the propositions or the cases should have a SPF that is in contradiction

with the propositions: the former study design is to extend the understanding of SPFs, whereas the latter to reshape the understanding of SPFs.

**Unit of analysis.** The unit of analysis in the study can be either a single SPF or multiple SPFs. However, for simplicity we only use the singular term 'SPF' in this description of CASFIS. The SPF is studied from all BAPO concerns and goes further into particular details of these concerns, such as the assets the SPF consists of and mechanisms used in implementation. Therefore the study design is, according Yin's [19] terminology, *embedded*, because it includes in addition to SPF also its subunits.

### 2.2 Preparing data collection

**Field procedures.** A study using CASFIS takes place in a company developing a SPF, which is an uncontrolled situation for this type of a study. At least two investigators participate in the interview. The investigators familiarize themselves with CASFIS, especially the study propositions and the case study questions, prior visiting the company. The investigators are prepared to present the case study questions and their associated figures to the responders, e.g., by a data projector or as printouts.

**Case study questions.** CASFIS includes case study questions as a central element. These serve a dual role: on the first hand, they are interview questions to be asked from responders, on one hand, they serve as a guideline how an interview should proceed and to structure the interview. That is, the interviews follow principles of a semi-structured interview. An interviewer can omit some questions that seem unimportant for the particular SPF, change the wordings and the order of the questions, and ask additional questions for clarification and deepening of the topic under discussion. In addition, an interviewer can ask additional questions in addition the questions in CASFIS. Additional questions can be, for example, summarizing comments in a question format to generalize the responses and enable the respondents to correct misinterpretations and misunderstandings, or questions that go deeper to a particular topic of interest. However, the questions also structure an interview. A deviation from the structure may lengthen the study and distort the focus.

The case study questions are available in [24]. The questions are mostly open-ended in order to enable true semi-structured interview and to achieve a rich qualitative description [28]. The structure of the questions (Figure 1) is broken down into business, artifact, process, and organizational (BAPO) concerns, similarly to what is described in [10]. Roughly one quarter of the questions cover the business and organizational concerns, another quarter covers the process concern, another quarter covers artifact concern in general, and the remaining quarter covers specially variability in the artifact concern. The term 'architecture' is replaced with the term 'artifact' in order to emphasize that the term referred to several kinds of assets in addition to the software architecture alone. The division to concerns was done to take into account several points of views to a SPF. Each concern is in own section in the questions. For each concern several *aspects* are identified that are properties of the concerns. For each aspect there

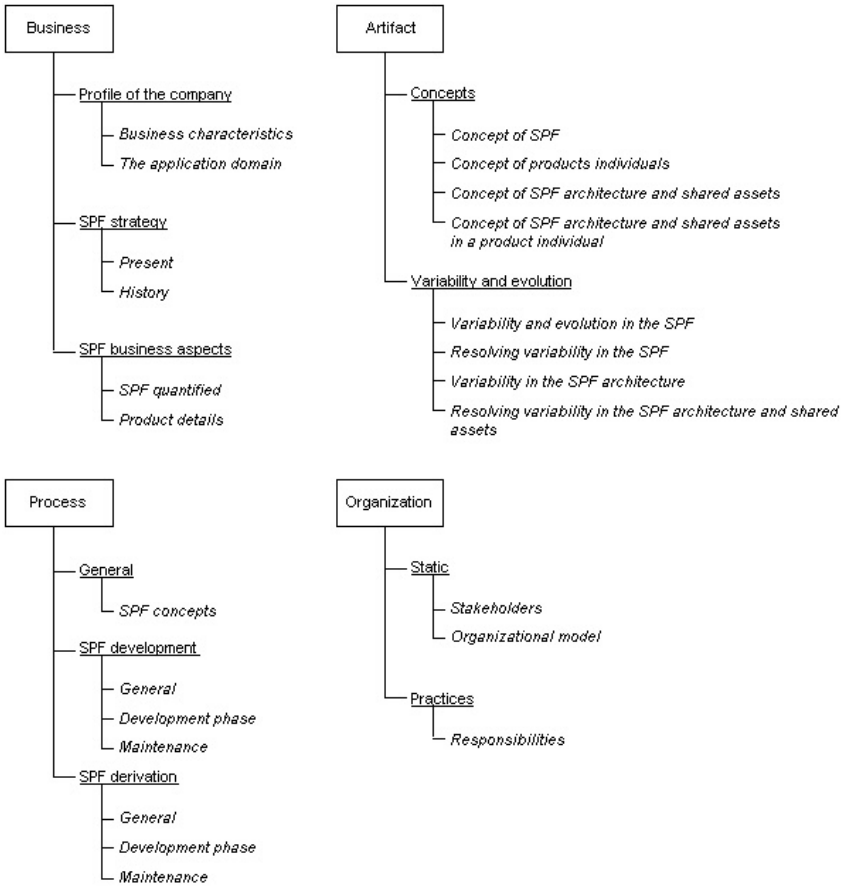


**Fig. 1.** Summary of the structure of the questions in CASFIS

is a set of *factors* that characterize the aspects. Finally, the questions measure the factors and, in addition, each section concludes with explicit question of what is important to success and problems in SPF. Since each section represent different point of view following the BAPO concern, some questions are repeated in all sections. An outline of concerns and aspects are presented as follows.

**Business.** The business concern covers *profile of the company*, *SPF strategy*, and *SPF business aspects*. Profile of the company includes *business characteristics* and *the application domain* factors. Business characteristics illustrate the internal characteristics of the company in terms of size and turnover, for example. The application domain illustrates the environment in for which the SPF is developed such as the kind of products in SPF and whether the software is embedded. SPF strategy include *present* and *history* factors. The present factor characterizes how SPF is perceived from the point of view

of business today while the past factor characterizes how the change to SPF has taken place. The SPF business aspect includes *SPF quantified* and *product details* factors. SPF quantifies concerns number of products individuals and prices. The product detail deals with detailed characteristics of product individuals in a SPF such as commonalities and variability.

**Process.** The process concern covers *general aspects*, *SPF development* and *SPF derivation*. The general concern consists of the *SPF concepts* aspect that deals with understanding of SPF and nature of division of processes to development and derivation phases. The SPF development aspect consist of *general*, *development phase*, and *maintenance* factors. The general factor deals with phases and activities, and organizing them in SPF asset development whereas development phase factors deals with how these activities are performed. The maintenance factor outlines maintenance process of assets such as change requirements. The SPF derivation aspects is consist of the same factors as SPF derivation, except, naturally, these deal with product individuals instead assets.

**Organisation.** The organization concern is divided into *static* and *practices* aspects. The static aspect deals with existing structure including the *stakeholders* and *organizational model* factors. The stakeholders deals with those individual involved in SPF development, whereas the organizational model deals with how these individuals are organized. The practices aspect concerns how organization operates consisting of *responsibilities* factor that deals with who is responsible of what in the SPF.

**Artifact.** The artifact section covers *concepts* and *variability and evolution* aspects. Concepts aspect deals with concepts of main artifacts in a SPF consisting of factors the *concept of SPF*, *concept of products individuals*, *concept of SPF architecture and shared assets* and *concept of SPF architecture and shared assets in a product individual*. The concept of SPF deals with how a SPF is understood as a whole, while the concept of products individuals aspect deals with product individual that the SPF includes. The last two aspects deal with what kind of pieces the SPF consists of and how these pieces are reuse in product individual, respectively. Variability and evolution consists of the *variability and evolution in the SPF*, *resolving variability in the SPF*, *variability in the SPF architecture*, and *resolving variability in the SPF architecture and shared assets* factors. These factors in the order introduced deal with how variability and evolution are perceived in the SPF, handled and mean in product individuals, embedded in the shared assets and SPF architecture, and handled and resolved when the shared assets and SPF architecture are used in product individuals.

### 2.3 Collecting evidence

**Introduction.** At the beginning of data collection in a study using CASFIS, the background, and objectives of the study are described to all responders. These responders are people involved in development of the SPF under study. The intention of the overview is to introduce the topic and focus the scope of the interview. These can be done to all

responders at once or each of them separately. For each respondents is also made clear that they are handled confidentially such that she or he could not be identified. Simultaneously is also assured that the responders are handled anonymously in order to gain trust and ensure that the responses are honest without fear of allegations. This, because it is not necessary to identify particular person, because the unit of analysis is a SPF, not a person or her acts. Further, it could be decided that the company would have a possibility to read the reports in order to avoid releasing, e.g., confidential information or details on the products.

**Interviews.** Data collection in CASFIS is carried out in an interview by recording and taking notes, and in a document analysis. The notes back-up the tapes and add details that are not available on the tape such as non-verbal communication or changes in tones of the voice. The interview is later transcribed. Data collection can include also taking photos. One investigator acts as main interviewer while other observes, takes notes, and asks occasionally questions that remained unclear. This in order that there is a one who focuses on detail and other who focuses on understanding the whole. However, during the study these roles can be rotated.

In order to ensure that different points of views are taken account, interview is carried out in three sessions: the first, the business session, and the second, process and organization session take both about an hour, and the third, artifact session, takes about two hours. The responders in business section are people in roles that define the course of the company and the products derived from the product family. They can be, for example, a product manager, a sales manager or an executive level manager. The same people are used in process and organization sections. These responders are people familiar with the processes in the company, manage them and possibly even have developed and defined them. They should be also familiar with the organization. Examples of such people interviewed are a product manager, a project manager and a human resource manager. Responders in the artifact section are technically oriented and have experience of the practices how things are done. These are people, e.g., lead software architect and an experienced software engineer.

**Case study database.** The data collected using CASFIS are stored in a *case study database*. This storage of data includes all data achieved, for example, recording, notes, and received documents. The storage can be electronic, but the practice has shown that some material is not electronic and to complement electronic storage is needed also a physical storage as well. When data is used, analyzed, or added in the database, a chain of evidence is kept. That is, all relevant leads from one data form to other data form are kept as well as metadata. For example, even if interviews are transcribed, the original recordings are not deleted and metadata of an interview includes details such as date, participants, durations, and place.

### 2.4 Analysis and reporting

CASFIS does not suggest or require any particular analysis approach. Data analysis can follow, for example, as Yin [19] and Eisenhardt [25] suggest, theory testing approach or

the data analysis may be based on grounded theory [29] approach to build novel theory on study propositions. Similarly as with the analysis approach, the logic linking data to propositions and criteria for interpreting the results are not fixed in CASFIS.

## 3 Rationale and usage guidelines for CASFIS

In the previous section, we presented CASFIS to study SPFs qualitatively. The approach we suggest does not advocate any particular philosophical point of view to the science, but tries to adhere to and combine approved qualitative study practices in the context of a SPF. By doing this, we took account and learned from the critique to software engineering research. CASFIS helps to gain more empirical results to increase and strengthen the body of knowledge on SPFs in a reliable way. In this section we further discuss our the design decisions of CASFIS, and outline issues that need to be considered when using CASFIS.

### 3.1 Designing a study using CASFIS

Conducting a case study includes other issues besides those introduced in CASFIS; a study using CASFIS should include its own overview, objectives, and reporting objective, for example. These were not included in the framework because they vary from project to project.

A study can use CASFIS to gain understanding of a SPF. Since there are already case studies and, hence, there is not much need for repeating the basic understanding, we see two primarily uses for CASFIS. First, CASFIS can be used without changes to study an interesting SPF that contradicts or extends understanding of some aspects of a SPF. Second, CASFIS can be used as a tool for getting an overview and an easy start for studying a SPF before focusing on more detailed objectives of the study. That is, CASFIS can be used to achieve initial understanding of a SPF.

The reasons for use of theoretical sampling is that in quantitative studies the studied SPFs should be representative set of a larger set of SPFs in order to allow generalization from to the studied small set to the larger set or results should represent interesting properties of the studied set, but could not be generalized beyond that set. Instead, in qualitative research the selected SPFs should represent some interesting aspect from which an investigator can learn. The generalizations are theoretical instead to a population [30]. Further details for theoretical sampling can be found in [31] in which is used the term 'purposeful sampling' instead theoretical sampling and given more detailed strategies than CASFIS for sampling in qualitative research that can be used to select cases.

As noted CASFIS can be used in a case study involving one SPF or multiple SPFs. This, although initially CASFIS was developed to be used in case study of multiple SPFs. Benefits and applicability of single and multiple case study designs are discussed, e.g., in [25] [32] [19] but this discussion is out of the scope of this paper. On the other hand, the unit of analysis in CASFIS is only a SPF, not the whole company, but, on the other hand, a study could include more than one SPFs from one company. However, basic background information is needed about a company as well. Since SPF is a holistic

approach, we believe that the embedded design including multiple levels of analysis is suitable to study SPFs.

### 3.2 Preparing data collection

This version of CASFIS does not take account many aspect of preparing data collection such as training and preparation for a specific case study. Although these are important aspects of a case study, they do not belong to CASFIS. CASFIS gives a frame of reference in which the study is conducted by an investigator. In order that an investigator is able to use CASFIS he or she should have been received a proper education beforehand. A description of desired skills for and training of investigator are presented, e.g., in [19].

### 3.3 Collecting evidence

On important aspect of collecting qualitative data is triangulation. In the case of CASFIS, triangulation is achieved through collecting data from different sources and using multiple investigators. The sources are an interview and document analysis. Similar with triangulation is the use of the BAPO framework in the interview questions. This because the used division to the BAPO concerns encourages and enables responders of different roles and reflected different point of views on the software product family. Multiple sources describe the same issues and widen the perspective of the research. Adding further sources of information would introduce valuable information. However, this is outside of CASFIS and can be carried out as a follow up separate study as described earlier. CASFIS includes only two sources of evidence. This is because its purpose is to characterize a SPF rapidly. A study using CASFIS can add sources of evidence such as observations but then face a risk to extend duration of the study significantly.

CASFIS includes a notion of a case study database. It is our experience that this information should recorded extremely carefully, because it hard, or impossible, to find out, for example, duration of the interviews, and even inconvenient to ask certain information again if some data is lost. Since we did not include analysis approach in CASFIS, we either did not include the required form of data in the database.

### 3.4 Analysis and reporting

Currently CASFIS does not include any particular analysis approach. Consequently, no analysis guidelines are included. However, in order to give the reader some idea, we briefly describe the approach we have taken.

We have done analysis by following the principles of the grounded theory [29]. We analyzed the data from each company, first separately, and then across the cases. The purpose of this analysis strategy was to first gain a holistic understanding of the SPFs in each company and then to understand similarities and differences between SPF in each company. The analysis was based on a discussion of the impressions of the investigators who were present at the interviews, as well as on the recordings, the received

documentation, the written notes, and transcripts of the interviews. In the analysis, we used ATLAS.ti [33], which is an application designed for qualitative data analysis. After we had gained the initial understanding of the companies, we analyzed them through a special analysis framework.

## 4 Evaluation of CASFIS

Evaluation of CASFIS internally consists of an initial evaluation, and carrying out a case study. These were performed using an initial version of CASFIS. The evaluations were used to improve CASFIS. However, the current version does not differ drastically from the version used in these evaluations. Therefore, we did not see it necessary to repeat these evaluations with this revised version of CASFIS.

### 4.1 Initial evaluation

The first part of the initial evaluation resembled a focus group study setting [28] [34]. The technique used was to interview a responder and ask her to rephrase the interview questions in her own words in order to determine if the interview questions were understood as intended. The responder was a research colleague working in the same research project. She was naturally aware of the goals, intentions and terminology, but she had not participated in any of the phases in the design of CASFIS. She had been working in the industry with software development before joining the research group.

The second part of the initial evaluation was a pilot study in a simplified settings [28]. The pilot study was carried out at our office premises with only one responder. The responder was an employee in another research project who had been working with a SPF in industry. He tried to respond to all questions although he did not have knowledge on all issues. This was also a reason why this data was not used in further analysis. The pilot study also simulated the actual research settings. The practices for the interviews were rehearsed simultaneously as well.

### 4.2 Case studies conducted

CASFIS has been used in a case study in six companies. Some results have been reported in [21] [22] although the name CASFIS was not used at that time. These studies proved that CASFIS is feasible to capture the state of the practice of SPF in a company. The studies also report the actual use of the earlier version of the framework.

## 5 Related work

Closely related to CASFIS are other frameworks and tools to study SPFs and empirical studies that have used similar research methods as in CASFIS.

### 5.1 Other frameworks and tools

SEI workshop [35] that reports practices in SPF development uses approach in which a set of questions were given to industrial participants. These questions are also publicly available. Based on the questions the participants gave a presentation of the SPF in their organization. These questions could be considered as an extremely simplified framework or a basis for almost unstructured interview to study a SPF qualitatively. However, since the approach used in that study relies on companies presentation rather than researcher intervention by asking question, we do not regard is as a similar as CASFIS. Further, such approach does not necessarily yield to rich descriptions on its own without further inquiry.

The SPF technical probe [3] is a tool comparable with the CASFIS. However, all details of the technical probe are not available for use.

Bosch [36] has introduced a *maturity scale* for SPFs that, in practice, categorizes SPFs with respect to systematicity of the process for developing products in a family. The more systematic this process in a SPF is, the higher it is ranked on the scale. In conjunction with the maturity scale of SPFs are introduced categorization for artifacts and organization models that, however, correlate with the maturity scale. However, the maturity scale is only a scale to differentiate between SPFs and therefore does not include procedures for studying or evaluating a SPF.

In [23] is presented an *evaluation framework* for a SPF that, when used, gives an assessment at the level one to five in all four concerns of the BAPO framework. The evaluation framework is built on and extends the maturity scale. That is, artifact dimension in the evaluation scale is similar with the maturity scale. A company can use this framework to asses its position on the framework. Consequently, this evaluation framework is primarily self-assessment tool that result quantitative results. The evaluation framework currently lacks details for conducting such assessment presenting primarily the assessment scale. However, it seems that making such assessment gives also interesting qualitative data and even researchers external to the company can do such assessments.

Software Engineering Institute (SEI) at the Carnegie Mellon University has used two questionnaires to study for software product families [37][6]. These focus on characterizing SPF state of the practice in the industry quantitatively rather than qualitatively.

We have initially compared the studied SPFs with the evaluation framework and maturity scale. This showed that the data obtained using even the earlier version of CASFIS was able to provide enough data to asses the SPF on both these scales. However, a more rigorous evaluation of the data acquired using CASFIS to existing knowledge of SPF, including all other tools, remains as future work.

### 5.2 Empirical studies

Closely related to our work are other empirical studies of SPFs. We describe some of these studies in the following in terms of the issues in CASFIS. We do not include experience reports since they do not include these issues.

CelsiusTech case study [12] concerned initially software architecture but focused also on a SPF. Data was based on previous knowledge as one other had worked in company supplying CelsiusTech its development environment, previously published reports including marketing literature and a dissertation, interviews with more than two dozen key personnel lasting three days, and documentation analysis of Ada interface specification and documented development methodology and processes.

Bosch reports a case study of SPF architectures [11] and evolution [38] in Axis Communications AB and Securitas Larm AB. The study was carried out as interviews following a questionnaire with the system architects and technical managers. The questionnaire consisted of context, technological, process, business and organizational issues. That is, it was similar with our approach. The interviews were video-taped. Some cases included also documentation analysis.

Svahnberg and Bosch [39] report a case study of evolution in SPF architecture at Axis Communication AB. This study is carried out as unstructured interviews with key personnel and analysis of information in the intranet.

Bosch and Hösgtröm [40] report a case study of product instantiation in a SPF in Axis Communication AB. The study is carried out as detailed analysis of products in a SPF, discussions with system architects, and documentation analysis.

Jaring and Bosch [41] report out a case study to exemplify relevant variability issues in Rohill Technologies BV. Case study is carried out as semi-structured interviews using a questionnaire, short talks with developers, and document analysis. The responders in the interviews were the chief architect and the main developer, both separately. The interviews were preceded by an introductory talk at least a week prior to the interviews. The results of the interviews were discussed with the interviewees.

In addition to the case studies, there are studies that include relatively close participation in company in long term. These follows, in practice, the principles of action research [42]. Such studies include Salion and Cummins [3] and a study of six companies reported in [43]. However, further details of these are not feasible for further comparison because of different methodology.

In [6] are described, to best of our knowledge, the results of the only quantitative study regarding SPFs. This report gives the used questionnaire, response rates, data from the questionnaire, and analysis.

The above mentioned studies show that the approach we have proposed in this paper is relatively similar with the methods that many other researchers have used. However, the earlier studies focus more on reporting the results and do not give details of their research approach. That is, despite the method in these studies follow the standards of scientific methodology for case studies, CASFIS is the first published description with enough detail to be applicable for other researchers as well.

## 6 Conclusions

We have proposed CASFIS (**CA**se **S**tudy **F**ramework for **I**ndustrial **S**PFs) to study any SPF empirically. CASFIS is built on existing knowledge on SPF, such as division to BAPO concerns, and combined with rigorous procedures to carry out a case study. The procedures includes details for studying a SPF, including separate study questions.

The publicly available information should enable even an external researcher to use CASFIS.

We believe that the contribution of this paper can greatly advance the state of the art and practice in the investigation of industrial SPFs. This, we believe will work for the benefit of development of SPFs in companies as well as for the research on SPFs. Furthermore, there is now concrete material for a dialogue on SPF study methods and their further development.

We do not advocate this as the only way to study SPFs. On the contrary, this is only one piece in a methodological toolbox of scientific approaches that can be used to study SPFs. For example quantitative tools such as surveys complement CASFIS. As a future work item is to ensure that CASFIS is compatible with existing measures. That is, to check our data acquired using CASFIS in order to see how well CASFIS provides answers to existing knowledge and measures such as the SPF evaluation framework.

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## References

1. Weiss, D., Lai, C.T.R.: Software product-line engineering: a family based software development process. Addison Wesley (1999)
2. Bosch, J.: Design and Use of Software Architecture. Addison-Wesley (2000)
3. Clements, P., Northrop, L.M.: Software Product Lines: Practices and Patterns. Addison-Wesley (2001)
4. Parnas, D.L.: On the design and development of program families. IEEE Transactions on software engineering **17** (1976) 40–52
5. Knauber, P., Bermejo, J., Böckle, G., do Prado Leite, J.C.S., van der Linden, F., Northrop, L.M., Stark, M., Weiss, D.: Quantifying product line benefits. Lecture Notes in Computer Science **2290 (PFE-4)** (2002) 155–163
6. Cohen, S.: Product line state of the practice report. Technical Report CMU/SEI-2002-TN-017, Software Engineering Institute (2002)
7. Tracz, W.: Software reuse myths. ACM SIGSOFT Software Engineering Notes **13** (1988) 17–21
8. Frakes, W.B., Fox, C.J.: Sixteen questions about software resue. Communications of the ACM **38** (1995) 75–87
9. Morisio, M., Ezran, M., Tully, C.: Success and failure factors in software reuse. IEEE Transactions on software engineering **28** (2002) 340–357
10. van der Linden, F.: Software product families in europe: The esaps and cafe projects. IEEE Software **19** (2002) 41–49
11. Bosch, J.: Product-line architectures in industry: A case study,. In: Proceedings of the International Conference on Software Engineering. (1999)
12. Brownsword, L., Clements, P.: A Case Study in Successful Product Line Development. Technical Report CMU/SEI-96-TR-016, Carnegie Mellon University, Software Engineering Institute (1996)

13. van Ommering, R.: Building product populations with software components. In: Proceeding of the Internation Conference on Software Engineering (ICSE'02). (2002)
14. Jaaksi, A.: Developing mobile browsers in a product line. IEEE Software **19** (2002) 73–80
15. Shaw, M.: What makes good research in software engineering? International Journal on Software Tools for Technology Transfer **4** (2002) 1–7
16. Glass, R.L.: The software research crisis. IEEE Software **11** (1994) 42–47
17. Tichy, W.F.: Should computer scientists experiment more? Computer **31** (1998) 3–40
18. Kitchenham, B.A., Pfleeger, S.L., Pickard, L.M., Jones, P.W., Hoaglin, D.C., Emam, K.E., Rosenberg, J.: Preliminary guideline for empirical research in software engineering. IEEE Transactions on software engineering **28** (2002) 721–734
19. Yin, R.K.: Case study Research. 2nd edn. Sage (1994)
20. Raatikainen, M.: A research instrument for an empirical study of software product families. Master's thesis, Helsinki University of Technology (2003)
21. Raatikainen, M., Soininen, T., Männistö, T., Mattila, A.: Characterizing configurable software product families and their derivation. Software Process: Improvement and Practices, Special issue on Software Variability: Process and management **to appear** (2005)
22. Raatikainen, M., Soininen, T., Männistö, T., Mattila, A.: A case study of two configurable software product families. LNCS 3014, (Proc. of PFE-5) (2004)
23. van der Linden, F., Bosch, J., Kamsties, E., Känsälä, K., Obbink, H.: Software product family evaluation. Lecture Notes in Computer Science (Proc. of SPLC 2004) **3154** (2004)
24. Raatikainen, M., Soininen, T., Männistö, T.: Case study questions for studying industrial software product families. Technical Report HUT-SoberIT-C10, Helsinki University of Technology, Software Business and Engineering Institute (2004)
25. Eisenhardt, K.M.: Building theories from case study research. Academy of Management Review **14** (1989) 532–550
26. McGregor, J., Northrop, L.M., Jarrad, S., Pohl, K.: Guest editor's introduction: Initiating software product lines. IEEE Software **19** (2002) 24–27
27. van Ommering, R., Bosch, J.: Widening the scope of software product lines - from variation to composition. Lecture Notes in Computer Science (SPLC2) **2379 (SPLC2)** (2002) 328–346
28. Foddy, W.: Constructing questions for interviews and questionnaires. Cambridge University Press (1993)
29. Strauss, A., Corbin, J.: Basics of Qualitative Research. 2 edn. Sage (1998)
30. Maxwell, J.A.: Understanding and validity in qualitative research. Harvard Educational Review **62** (1992) 279–300
31. Patton, M.Q.: Qualitative evaluation and research methods. 2 edn. SAGE (1990)
32. W. G. Dyer, J., Wilkins, A.L.: Better stories, not better constructs to generate better theory: A rejoinder to eisenhardt. Academy of Management Review **16** (1999) 613–619
33. ATLAS.ti: Scientific software development, atlas.ti user's manual and reference, version 4., http://www.atlasti.de/ (2004)
34. Kitchenham, B.A., Pfleeger, S.L.: Principles of survey research: part 3: constructing a survey instrument. ACM SIGSOFT Software Engineering Notes **27** (2002)
35. Bass, L., Clements, P., Cohen, S., Northrop, L., Withey, J.: Product line practice workshop report. Technical Report CMU/SEI-97-TR-003, Carnegie Mellon University, Software Engineering Institute (1997)
36. Bosch, J.: Maturity and evolution in software product line: Approaches, artefacts and organization. Lecture Notes in Computer Science **2379 (SPLC2)** (2002) 257–271
37. SEI: Product production questionnaire, http://www.sei.cmu.edu/plp/production%5fquestionnaire.html (2004)
38. Bosch, J.: Evolution and composition of reusable assets in product-line architectures: a case study. In: First Working IFIP Conference on Software Architecture (WICSA1). (1999)

39. Svahnberg, M., Bosch, J.: Characterizing evolution in product line architectures. In: IASTED 3rd International Conference on Software Engineering and Applications. (1999)
40. Bosch, J., Högström, M.: Product instantiation in software product line: A case study. In: Second International Symposium on Generative and Component-Based Software Engineering (GCSE 2000), October 2000. (2000)
41. Jaring, M., Bosch, J.: Representing variability in software product lines:a case study. In: Lecture Notes in Computer Science 2379, Proceedings of the second software product line conference. (2002)
42. Avison, D.E., Francis, L., Myers, M.D., Nielsen, P.A.: Action research. Communications of the ACM **42** (1999) 94–97
43. Knauber, P., Muthig, D., Widen, T.: Applying product line concepts in small and medium-sized companies. IEEE Software **17** (2000) 88–95

## Appendix

Examples of questions from [24]. The major numbering refers to BAPO as follows: B = 1, P = 2, O = 3, and A = 4. This is counterclockwise order of concerns in Figure 1 starting from the business concern. The second number refers to the aspect within concern, and the third number refers to the factor. These are same as top-down order of aspects and factors under each concern in Figure 1. The last number is identification of the question. For example, the question Q:1.3.2.6 refers to business concern, SPF business aspects, products detail factors, and question number six (cf. Figure 1).

- Q:1.2.1.4 How do sales and marketing influence on development of the product family?
- Q:1.3.2.4 Differences are opposite of commonalities, i.e. characteristics that make instances of the product family different. From the customer or sales viewpoint, what are the differences in products in the product family?
- Q:1.3.2.6 What is most important to success in product family development?
- Q:2.2.1.4 Is the process documented or modeled? If it is, what kind documentation is there?
- Q:3.1.1.1 What are the stakeholders that has influence on the product family and what kind of and how strong their influence is?
- Q:4.1.3.1 How does the company define and understand the product family architecture?
- Q:4.1.3.11 What are examples of reusable software entities in the product family?
- Q:4.2.1.1 Variability can concern e.g. functionality, user interface, quality, performance, platform, or underlying hardware. What varies in the product family?
- Q:4.2.1.2 What is the reason for variability in the product family?
- Q:4.2.3.15 What is the reason for the evolution of the product family architecture?