

Families Task 1.3 CWD

Family Marketing, Domain and Scoping Economics

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UNIVERSITY OF JYVÄSKYLÄ

Work Package 1
Reuse Economics and Family Transition


The deliverable „Family Marketing, Domain and Scoping Economics“ focuses on determining the Economic Situation of the pl and establishing the relationship of the individual decisions within product line development.

The different approaches described in this deliverable cover the different dimensions of the BAPO approach. A certain focusing is however made with respect to the architecture dimension.

The deliverable consists of two chapters.

While the first one focuses on the development of business strategies, the second one focuses on implementing these strategies.





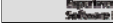




Introduction: Family Marketing, Domain and Scoping Economics

Authors (alphabetical order by family name):

Piergiorgio Di Giacomo (ESI)
 Rauli Käppi (University of Jyväskylä)
 Eelco Rommes (Philips)
 Kai Vuolajärvi (University of Jyväskylä)
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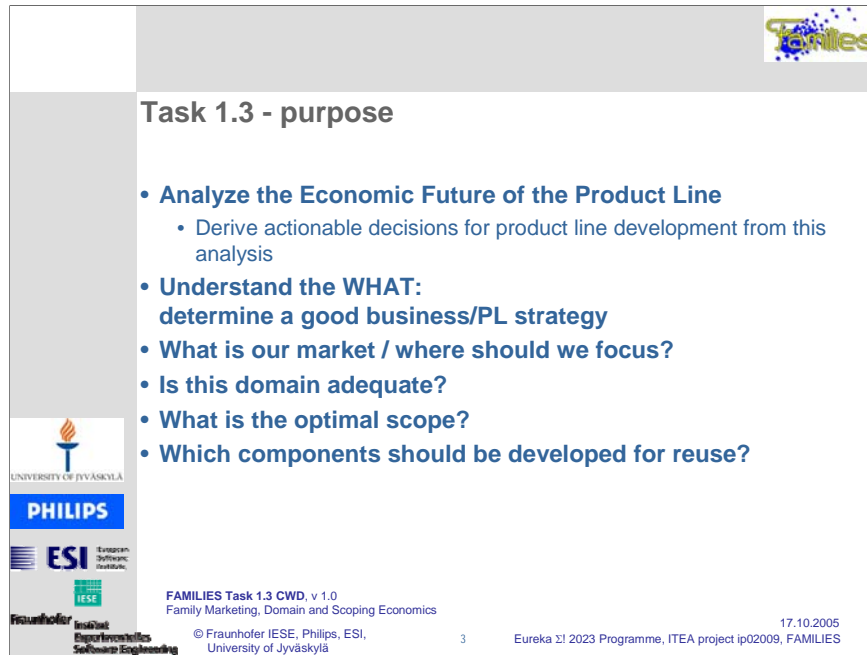
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In more detail the purpose of Task 1.3 can be explained as developing methods and tools, as well as gather experience on:

- Analyzing the economic future of the product line: understand where the product line is going as otherwise a successful product line investment is rather unlikely.
- It is key that a successful product development strategy supports the product line as product sales is the ultimate, underlying rationale for all product line decisions.
- The development of such a strategy is always based on the market and the domain. In particular it is important to determine whether the product line domain is adequate.
- This in turn provides a basis for deriving an optimal product line scope.
- Finally, issues like which components shall be developed should be derived from the methods.



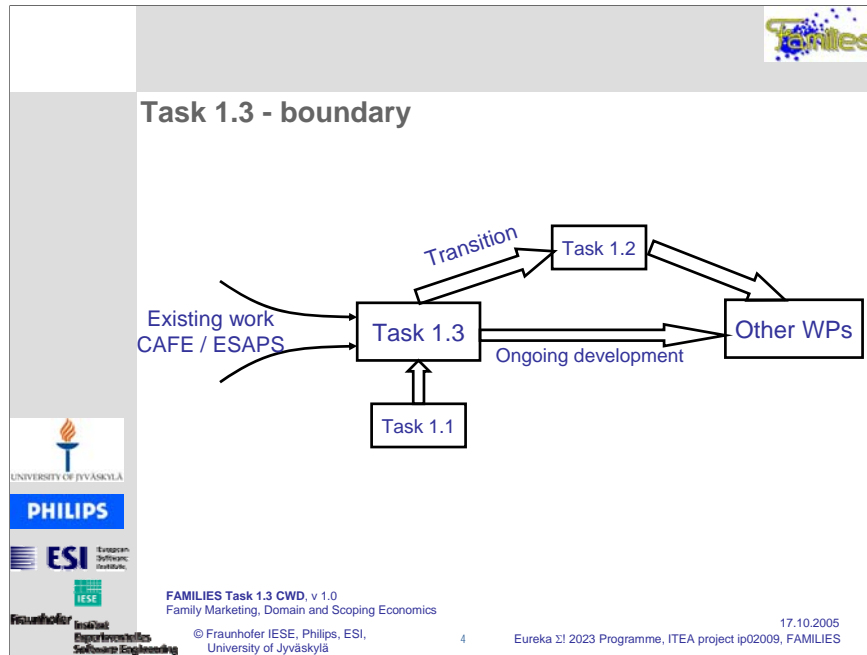
Task 1.3 - purpose

- **Analyze the Economic Future of the Product Line**
 - Derive actionable decisions for product line development from this analysis
- **Understand the WHAT: determine a good business/PL strategy**
- **What is our market / where should we focus?**
- **Is this domain adequate?**
- **What is the optimal scope?**
- **Which components should be developed for reuse?**

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- Finally, issues like which components shall be developed should be derived from the methods.



Task 1.3 is strongly embedded in the other tasks.

It leverages on existing work from ESAPS and CAFE. Task 1.1 is supposed to provide input in terms of underlying investment models for the product line. The results of Task 1.3 are supposed to provide a basis for the other work packages. It also informs Task 1.2, which has a much stronger focus on the actual transition towards product line engineering.

Roughly spoken Task 1.3 provides a continuous decision-making basis for the product line engineers, while Task 1.2 specifically focuses on the transition phase.

This concept was established early on and provided the initial basis of the work for Task 1.3. This initial concept was only partially fulfilled. In particular, the interaction with existing work from Café was only partially realized. Furthermore, the coordination of work in Task 1.2 and in Task 1.3 could only partially be realized.



Overview of Contributions

Chapter 1: Development of Business Strategies

- **University of Jyväskylä:** Organizational maturity - assessment and incremental development
- **ESI:** Reuse Action Plan Impact in the FEF-A-Dimension
- **Philips:** A Rational Product Family Architecture Roadmapping Process

Chapter 2: Implementation of Business Strategies

- **Philips:** Linking Business Strategy to Architectural Decisions


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The deliverable is consists of the contributions named above.

The core theme of the deliverable is business strategies. This has been broken down into the definition and the implementation of business strategies.





Chapter 1: Development of Business Strategies

Organizational maturity: assessment and incremental development (University of Jyväskylä)

- Different configurations of the organization can be observed at different times in the evolution towards product families
- Combines theoretical analysis with Case Studies

Reuse Action Plan Impact in the FEF-A-Dimension (ESI)

- Development of RAP (Reuse Action Plan)
- Relates reuse strategies to development situations

Exploring the Future: Roadmap driven System Family Development (Philips)

- Systematic approach to derive PL roadmaps
- NPV analysis


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The first deliverable by University of Jyväskylä focuses purely on the organizational maturity of an organization. Unfortunately, it is at the same time the only deliverable with a reasonable focus on organizational aspects. Here different company configurations are analyzed with respect to their product family implications.

The deliverable by ESI relates the Reuse Action Plan (RAP) to the FEF-A dimension (i.e., Families Evaluation Framework; Architecture dimension). Here different development situations are related explicitly to reuse strategies.

The deliverable by Philips on Roadmapping addresses the derivation of PL roadmaps. The individual scenarios are addressed by a NPV analysis.





Organizational maturity: assessment and incremental development (University of Jyväskylä)

- Different configurations of the organization can be observed at different times in the evolution towards product families
- Configurations are described on the following levels (also evolution over time):
 - Business Strategy Level
 - Internal Process Level
 - Product Family Engineering Level
 - Software Product Development Level
 - Customer settings requirements
- Enables an organization to expect changes over time
- Supports selection of transition measures over time

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The first deliverable by University of Jyväskylä focuses purely on the organizational maturity of an organization. Unfortunately, it is at the same time the only deliverable with a reasonable focus on organizational aspects. Here different company configurations are analyzed with respect to their product family implications.

The deliverable describes certain organizational configurations that are typical in different steps of the product line development.


In the configurations, the following levels are differentiated:

- Business Strategy Level
- Internal Process Level
- Product Family Engineering Level
- Software Product Development Level
- Customer settings requirements

The characterization can be used in several ways:






- it can be used to predict future change, thus enabling the organization to be proactive and address the change before the situation gets problematic.
- In particular, the characterization can be used to select transition measures, as the goal of the transition is clarified.





Reuse Action Plan Impact in the FEF-A-Dimension (ESI)

- Defines reuse strategies (Reuse Action Plan = RAP)
 - Project-based reuse – minimal infrastructure, project organization drives whole organization
 - Production-center reuse – domain engineering organization is established
 - Domain-driven reuse – domain engineering is main driver
- Not all strategies map directly to a specific FEF architecture level!
- Relation between
 - RAP and situations where applicable
 - RAP and needed activities are given

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The deliverable by ESI relates the Reuse Action Plan (RAP) to the FEF-A dimension (i.e., Families Evaluation Framework; Architecture dimension). Here different development situations are related explicitly to reuse strategies.






The reuse action plan defines different levels of sophistication for reuse strategies. These different strategies are mapped to architectural approaches. These approaches do not map directly to FEF-levels. Rather the least sophisticated level – no product line – is (of course) not addressed by the RAP. Also the most sophisticated level – pure automation – is not addressed as it goes beyond the realms of traditional reuse strategies.





Exploring the Future - Roadmap driven System Family Development (Philips)

- Focus on development of scenarios of the future
- Based on CAFCR views (Customer, application, functionality, conceptual, realization)
- Establishes a model of architectural investments (architecture scenarios): NPV calculation
 - Investments
 - Income
 - Discount rate
- Architectural scenarios depend on strategic scenarios (market, application domain, technology)
- Focus on key success factors – and their architectural implementation
- Derive a roadmap that captures these success factors

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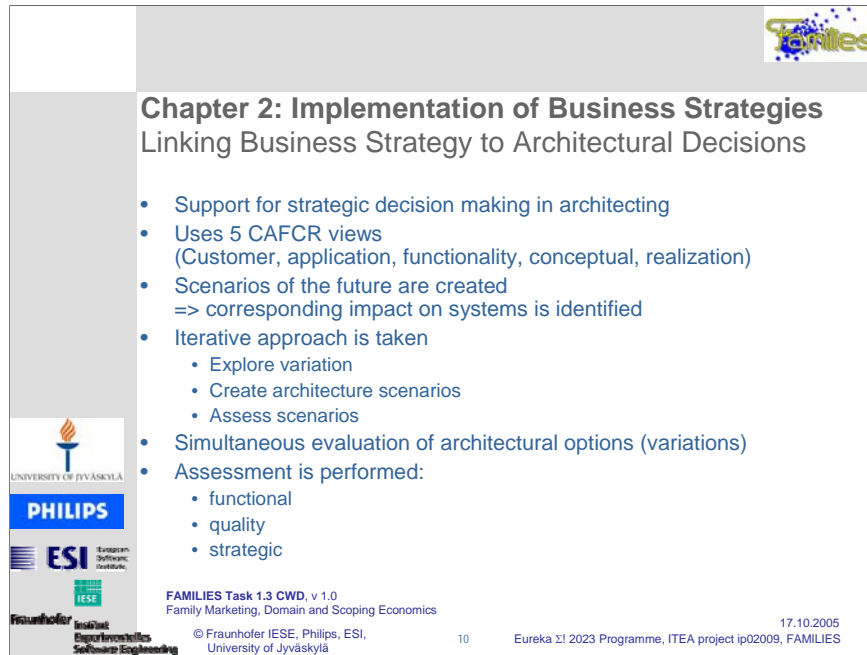
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The Philips deliverable on „Roadmap driven System Family Development“ needs to be discussed in context with the companion deliverable which belongs to the business strategy implementation section. In the deliverable here, it is described how scenarios of the future can be developed and from an investment position analyzed. The CAFCR-views are used for describing and deriving scenarios.

The investments are restricted to the architectural perspective and are analyzed in terms of an NPV analysis.

Architectural scenarios depend on strategic scenarios. From these strategic scenarios the key success factors are analyzed and a resulting architectural analysis is performed.

The success factors themselves provide a basis for the definition of the roadmap.



Chapter 2: Implementation of Business Strategies
Linking Business Strategy to Architectural Decisions

- Support for strategic decision making in architecting
- Uses 5 CAFCR views (Customer, application, functionality, conceptual, realization)
- Scenarios of the future are created => corresponding impact on systems is identified
- Iterative approach is taken
 - Explore variation
 - Create architecture scenarios
 - Assess scenarios
- Simultaneous evaluation of architectural options (variations)
- Assessment is performed:
 - functional
 - quality
 - strategic

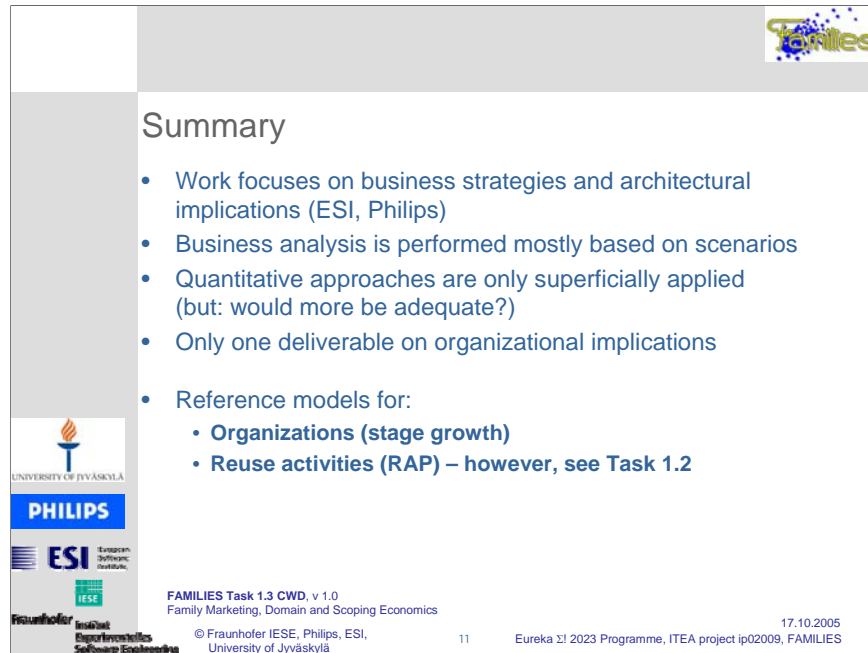
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The section „implementation of business strategies“ consists unfortunately only of a single deliverable: „linking business strategy to architectural decisions“
[Thus, there is also no specific section introduction.]

The deliverable extends the previous deliverable in terms of an architecture assessment approach which enables the evaluation of a complete architectural family; including its variation.

The assessment is performed on three different levels:

- functional
 - quality
 - strategic
- viewpoint.



Summary

- Work focuses on business strategies and architectural implications (ESI, Philips)
- Business analysis is performed mostly based on scenarios
- Quantitative approaches are only superficially applied (but: would more be adequate?)
- Only one deliverable on organizational implications
- Reference models for:
 - **Organizations (stage growth)**
 - **Reuse activities (RAP) – however, see Task 1.2**

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Summary:

Overall the CWD focuses strongly on business strategies and architectural implications.


The business analysis is not so much focused on quantitative models, but rather scenarios are used and defined in order to get a handle on the economic implications of a product family.

Unfortunately, there is only one deliverable on organizational implications.

The work describes several reference models:

- the stage growth model for organizations has been extended to cover product line organizations.
- the RAP (reuse action plan)





Chapter 1 – Development of Business Strategies (Overview)

Authors (alphabetical order by family name):

Kai Vuolajärvi (University of Jyväskylä)

A more detailed description of the contribution can be found in the book chapter “Scenario-Based Architecting: Harmonizing Short and Long Term Business Needs” by the same authors, on which this text is based.

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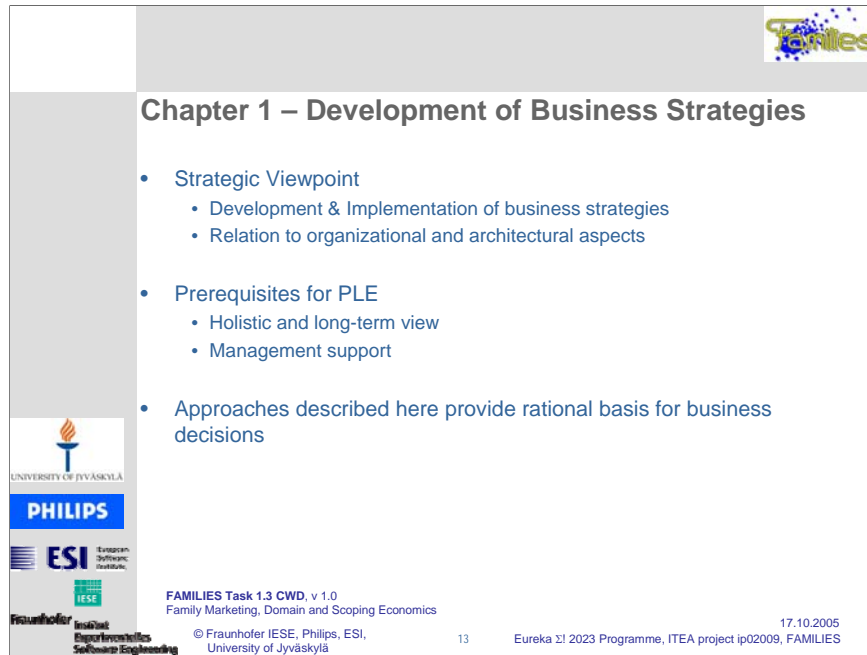
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The first chapter of the deliverable CWD 1.3 is entitled „Development of Business Strategies“ and consists of three deliverables:

- Organizational maturity - assessment and incremental development
- A Rational Product Family Architecture Roadmapping Process
- Reuse Action Plan Impact in the FEF-A-Dimension

They focus on the development of business strategies and their relation to organizational aspects, respectively their relation to the product line architecture.

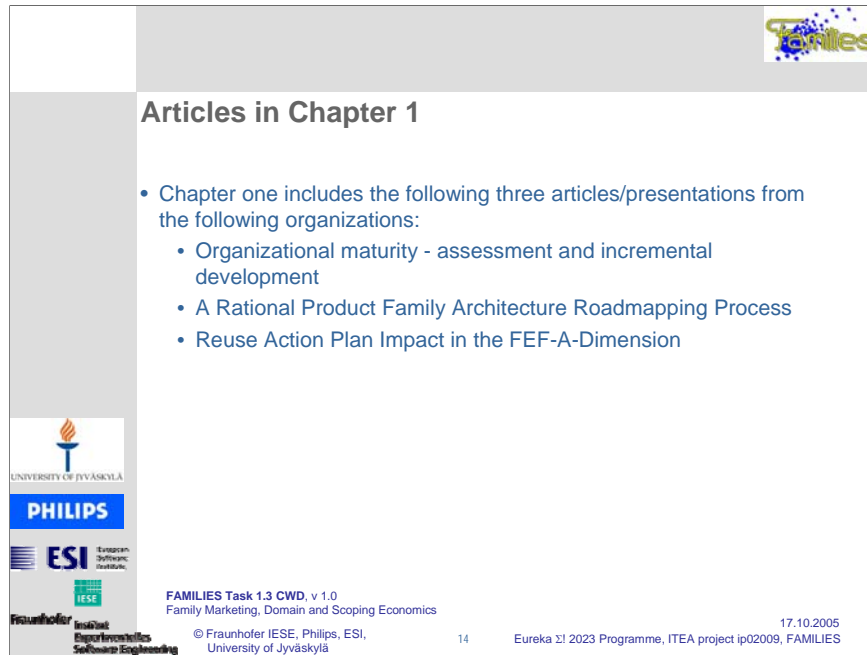


Chapter 1 – Development of Business Strategies

- Strategic Viewpoint
 - Development & Implementation of business strategies
 - Relation to organizational and architectural aspects
- Prerequisites for PLE
 - Holistic and long-term view
 - Management support
- Approaches described here provide rational basis for business decisions

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- Chapter 1 in task 1.3 takes a strategic perspective on product line engineering and examines from the business strategy development and implementation point of view the implementation and planning of the product line engineering approach in the organization
- In order to effectively establish the product line engineering in the company a holistic and long term view to the subject should be taken and there should be a strategic business decision to the issue, supported by full management support.
- Having a decision and support on PLE approach a strategic PLE development plan can be developed



Articles in Chapter 1

- Chapter one includes the following three articles/presentations from the following organizations:
 - Organizational maturity - assessment and incremental development
 - A Rational Product Family Architecture Roadmapping Process
 - Reuse Action Plan Impact in the FEF-A-Dimension

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- Three articles are presented in this section and through three articles a strategic view is taken to the product line engineering.
- In the first article this issue is viewed from the larger perspective, looking at overall development of software engineering company and identifying in this perspective development of PLE in different maturity stages of the company.
- Starting from this larger perspective, in second article the roadmapping of PLE architecture implementation in the company is examined.
- Third article in this chapter considers re-use of software assets in general and discusses three different strategies to re-use, namely Project-Based Reuse, Production Center Reuse and Domain Driven Reuse.



Introduction & Problem Description

- Improved growth / maturity model Based on the Stage growth model developed in Cafe project
- The research problem is to understand in which stage of their lifecycle companies typically experience strong pressure in their SW product development and hence start implementing new ways of carrying out their development

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The research domain are the new software product ventures, either in SMEs or large organization's venture units targeting new business domains through new channels.


A further problem is assessing how companies react to identified pressures and how fast / in which order they are able to come up with improvements to their software development practices.

The results are partially applicable to large organizations. However due to differences such as resourcing, financing, decision making and more complex organizational structure the results may need to be interpreted for the use of large organizations. For the researched domain the results should be used as is.








	<h3>Relevance & Expected Benefits</h3> <p>Software products, especially software product families impose several requirements for software companies aiming to create and deliver remunerative products to the markets. Two main problems this contribution deals with are:</p> <ol style="list-style-type: none">1. What alternatives do software product companies have when defining their product family scope and strategy in the early stages of the life-cycle of a product family?2. What type of transition processes are required from the companies both internally and externally to develop mature product family processes and align them with the rest of the company's development and goals?
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Approach & Expected Results

- Two assumptions are made in this study:
 - The companies in general (and in this model) do not start explicit Product Family Engineering practices when they start their business – the PFE-approach comes at a later stage if it does
 - This final model is not trying to analyze the development of a company which selects the PFE-approach in the very beginning, as this type of cases have not been studied in real life – instead a more gradual company approach to PFE-practices is chosen
- The results are: A theoretical model describing a “clean-slate-approach” to PFE-practices was created during this study, but was never verified due to missing case examples – another model describes a more gradual approach to PFE
- The expected results are the created model(s) which offer SW company management a clear, concise perspective to the evolution of their practices

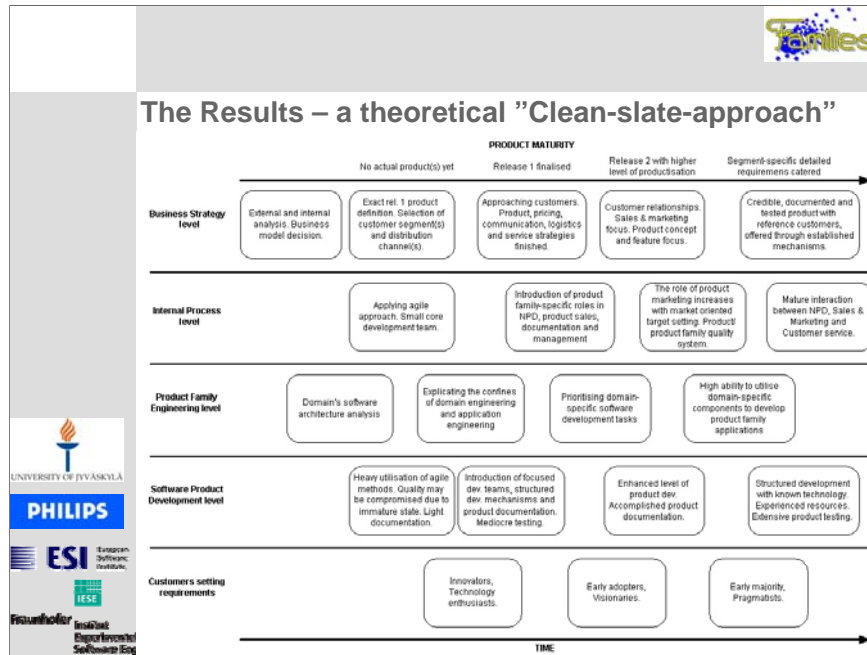
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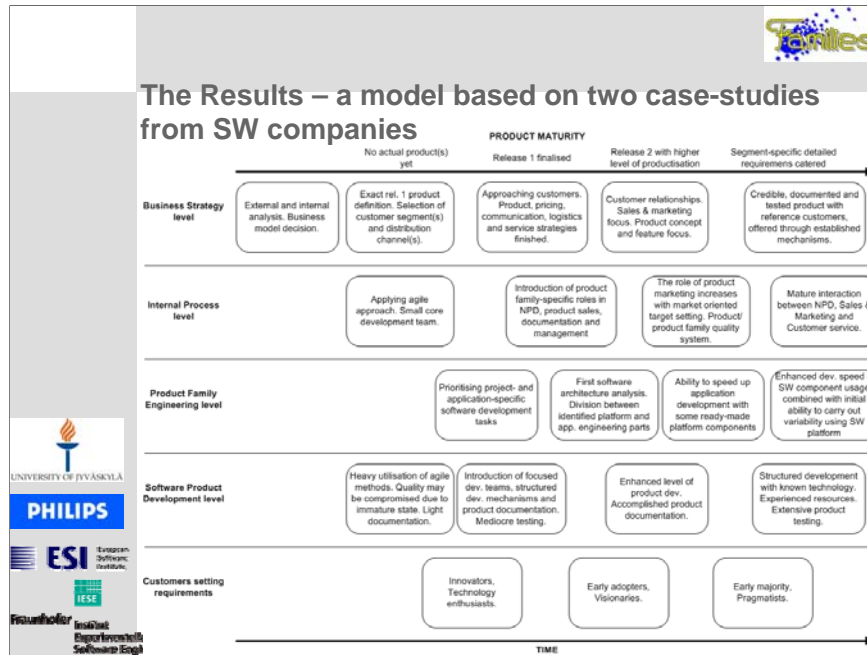
The assumption has been made that in a competitive environment companies must evolve and mature their execution in order to stay competitive. Regarding the researched Product Family Engineering – approach there are different timing alternatives to utilize it. These alternatives are reflected in the results and are applicable to companies depending on their actual PFE-timing.

The models offer the business and engineering management a holistic understanding (in a given point of time) of the probabilistic future strain points for the business, product, and organisational development of the software product company. It provides the management with the possibility to prepare for the situations proactively instead of facing the situations as they come and trying to reactively work with them.



This model has not been verified by any case study, but is based only on a literature study how PFE should be approached – this PFE-approach is then put to the context of earlier studied company growth / maturity framework. In this model the company is assumed to start the PFE in the very beginning of its existence.

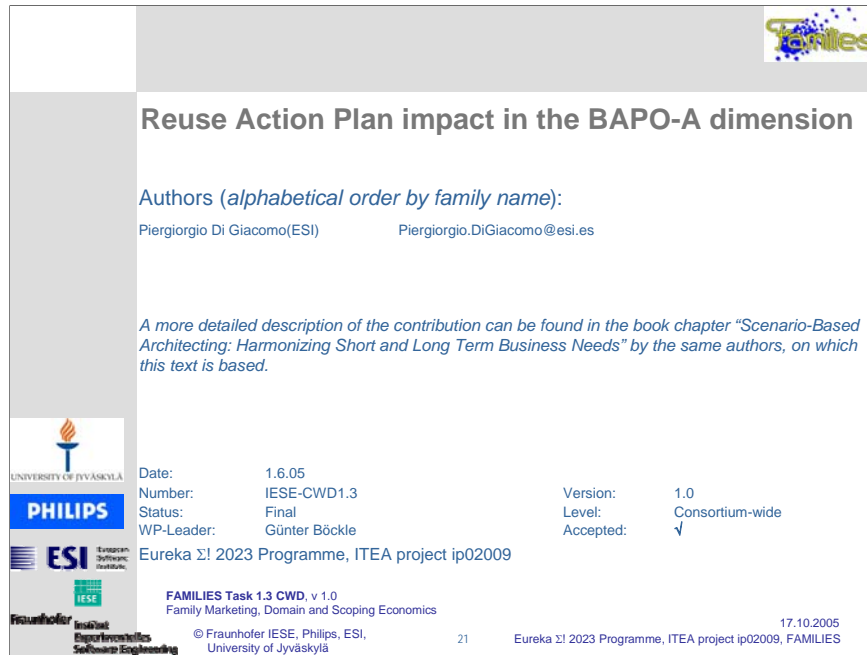
It is noteworthy that this work / model does not indicate that all companies develop this way – the development can stop for a number of reasons at any time or some level may develop faster than others. If the company experiences pressures to develop their practices, the model provides an understanding how to develop the company so that different levels actually benefit each other in parallel. If a company fails in gaining these benefits the model can be used to identify where and why resources are wasted due to over investing / under investing to some level's development while the organization cannot utilize those benefits in other levels.



The model offers an understanding of the current maturity of the company. This model illustrates the findings from real-life SW company case-studies. The findings suggest that these companies have emphasized other areas (such as product focus, finding the good markets, organizational development, strategy work, etc.) first. The studied companies / units have had to face the technical challenges of product variation with multiple products after they have reached a point of having multiple existing customers and products for them. This model displays what are the challenging organisational issues to be considered by the management when a PFE-approach is chosen as a solution of reaching better technical maturity.

In the model (left side) the companies typically are trying to assess the surrounding business environment and evaluate their product positioning in real life. Due to the high level of uncertainty only mandatory investments are approved. These investments include the necessary means of creating the organization and first version of the perceived SW product. There are no PFE investments made in the beginning and the development focus of the company is application driven. When moving to the right side, after the first release is out to customers, the organization needs to grow and evolve into having more specialized roles in every function of the company. Simultaneously the growing number of customers is causing strain in the R&D unit when the number of required variants is rising. This strain situation leads to the use of common components to improve the efficiency and throughput of the R&D.

As the situation develops towards the right side of the model the company already has a very developed organization and is competing in a more mature market than in the beginning of the model. In this type of mature market situation the factor of time-to-market and ability to create multiple variants quickly has risen in importance significantly. Hence the application driven approach with the use of components is matured into a platform driven product family approach on the very right side of the model to support the increased performance level requirements of the company.



Reuse Action Plan impact in the BAPO-A dimension

Authors (alphabetical order by family name):
Piergiorgio Di Giacomo(ESI) Piergiorgio.DiGiacomo@esi.es

A more detailed description of the contribution can be found in the book chapter "Scenario-Based Architecting: Harmonizing Short and Long Term Business Needs" by the same authors, on which this text is based.

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Abstract

The purpose of this study is to map RAP strategies to the five level approach of BAPO Architecture Dimension. This provides, within the reuse action plan, some specification of the maturity of the Architecture dimension of the organization with respect to the BAPO

Relationships to and Dependencies on other Tasks and Previous Projects

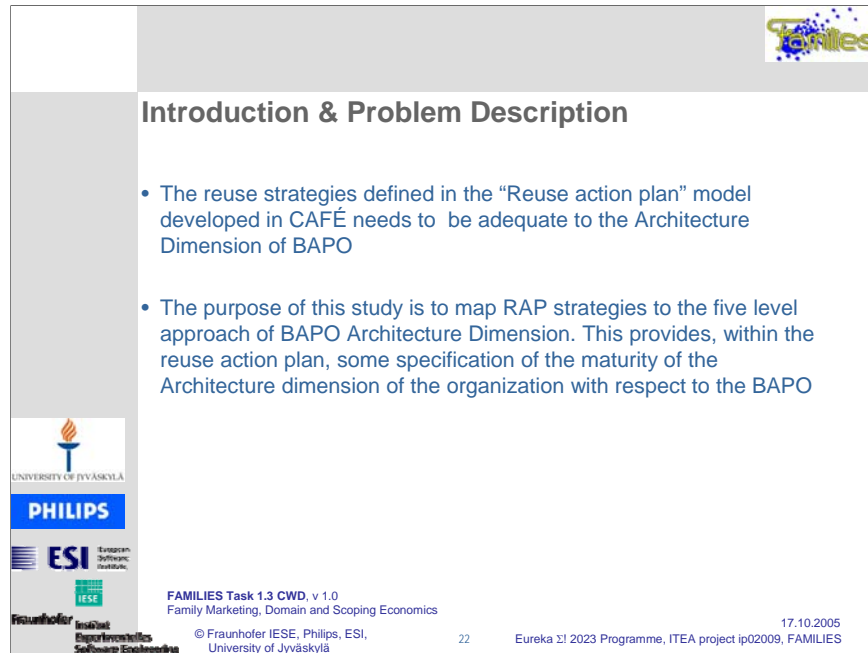
This work extends the Reuse Action Plan developed in Café project and is related to phases 2 and 8 of the Families process.

Book Chapter

No

Keywords

Reuse, BAPO, Architecture, Reuse strategy



Introduction & Problem Description

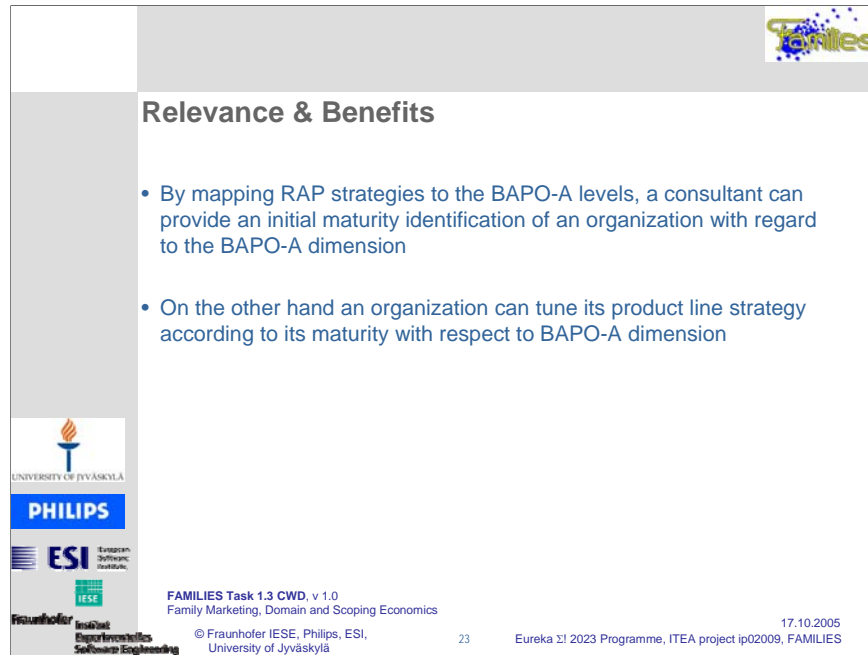
- The reuse strategies defined in the “Reuse action plan” model developed in CAFÉ needs to be adequate to the Architecture Dimension of BAPO
- The purpose of this study is to map RAP strategies to the five level approach of BAPO Architecture Dimension. This provides, within the reuse action plan, some specification of the maturity of the Architecture dimension of the organization with respect to the BAPO

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Introduction

“Reuse action plan” is a model developed in the CAFÉ project. It provides three different strategies for implementing software reuse within an organization. The final target of RAP is not only to define such strategies, but also to choose the one that better fits the expectations of each specific company with respect to its size, needs, knowledge etc.

This work adequate the content of RAP to the Architecture Dimension of BAPO. The purpose of this study is to map RAP strategies to the five level approaches of BAPO Architecture Dimension. This provides, within the reuse action plan, some specification about the maturity of the Architecture dimension of the organization with respect to the BAPO



Relevance & Benefits

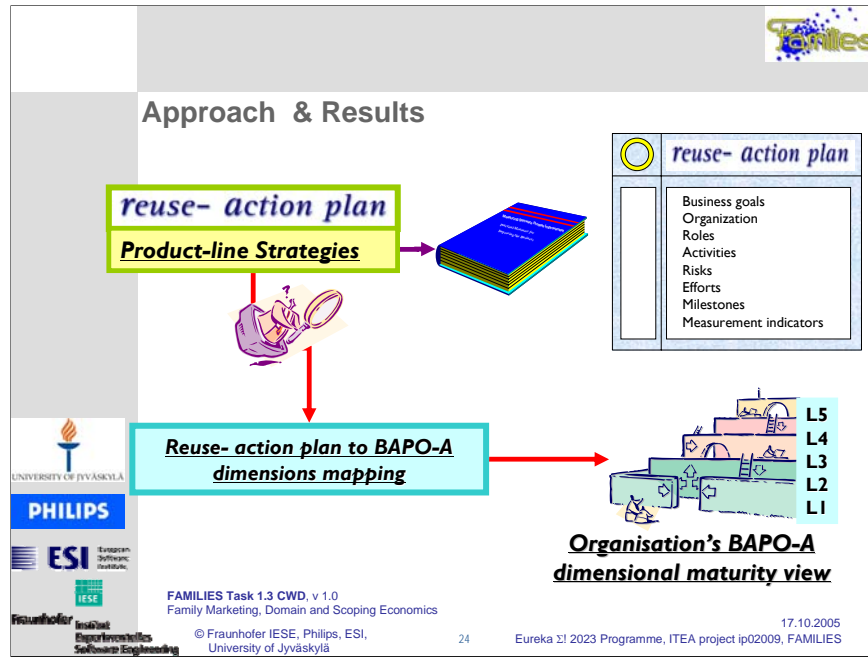
- By mapping RAP strategies to the BAPO-A levels, a consultant can provide an initial maturity identification of an organization with regard to the BAPO-A dimension
- On the other hand an organization can tune its product line strategy according to its maturity with respect to BAPO-A dimension

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Benefits


The benefit of mapping RAP to BAPO-A is double:

- From the point of view of the consultants it is possible, to define the level of maturity of an organization (with regards to the BAPO-A dimension) evaluating the Reuse strategy it is using.
- On the other hand, a company can assess its BAPO maturity and then, knowing its maturity level in the Architecture dimension, can use this information as an additional input for choosing its reuse strategy.
- Finally, if a company wants to achieve an architectural maturity level upgrade, this implies the change of the implemented reuse strategy. So, both the consultant and the company are more aware of the risks to mitigate and the task to accomplish in order to achieve the next maturity level






The picture shows the approach followed to accomplish the task explained in the previous two slides





What is RAP

- Reuse-action plan consists of determining a reuse strategy that better suits companies needs, by ensuring:
 - Business orientation: success of the strategy is measured in business terms using a balanced scorecard approach.
 - Low entry-level: low investment before you start obtaining benefits using "light weight" approach
 - Low risk: use an iterative incremental adoption to get early feedback to enable early corrective actions and keep up enthusiasm and increment commitment

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Reuse-action plan objective is to establish a strategic plan for the implementation of systematic reuse in a specific organisation. Each company needs to develop its own approach to adopt reuse practices considering factors such as existing reuse practices, business sector, organisation's culture and maturity, level of standardisation in technology and domain, etc.

A reuse initiative may range from a modest infrastructure of reusable components to a complete architectural platform and domain-specific environment for application derivation (but more sophistication in the approach does not necessarily mean better results).

The main steps of RAP process are:

- Define and quantify the business objectives for the organization
- Align the technical actions and tasks with the top-level business-objectives
- Establish the appropriate measures to manage and track the implementation of the plan effectively.



Reuse Strategies in RAP

- RAP provides three different strategies to implement according to the level of reuse an organization is willing to achieve:
 - Project-Based Reuse
 - Production Center Reuse
 - Domain Driven Reuse
- In the three cases the reuse level is incremental and the relative importance of AE vs. DE activities is balanced as follows:

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RAP method helps in the development of a Reuse Strategy Plan within a company, using a specific Reuse Strategy and Metrics models (provided in RAP reference documents).

The Reuse Strategy model is divided into three different reuse scenarios each with a set of activities to perform. Each of these scenarios represents different reuse infrastructures to implement in a company regarding the resources available and desirable result to obtain.

The Metrics model is divided into the five perspectives: Financial, Customer, People, Process and Infrastructure & Innovation. Each of these perspectives comes with a set of predefined goals to be achieved, drivers of success and indicators for monitoring goals and drivers.






This method is divided into three big actions that result in the final Reuse Strategy Plan. Each of these actions contains several steps that must be followed in order.





Reuse Strategies in RAP

- **Project-based reuse**
 - A domain is identified.
 - A minimal infrastructure (e.g., a shared component repository) is put into place to collect reusable assets in the domain.
 - Project plans explicitly include reuse with the main objective of decreasing project costs, but without introducing major changes in the application development process.
 - Reusable assets are produced as part of project development (no independent production of reusable assets).

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Main characteristics of Project-Based Reuse strategy:


- The identification of the legacy products is undertaken by the members of the projects by identifying potential reusable assets that have been identified in past projects. The identification is done when a project plan requires so. No future needs are covered or looked upon
- The reusable assets are developed with basic documentation (ex. Main functionality and an example of use). Asset users are expected to reuse existing assets without specific support.
- Specific activities are included in the application engineering processes so as to allow the development of reusable assets and searching for candidate reusable assets. Each phase of the project life cycle (requirement gathering, design, etc.) includes specific reuse activities such as finding reusable assets, selecting the most appropriate one, modifying it if necessary, integrating and providing feedback. Furthermore, it includes specific activities for building / acquiring / reengineering reusable assets.
- Reuse efforts are oriented entirely to supporting the current needs of application engineering projects. DE gives priority to the immediate needs of projects to satisfy customer requirements.





Reuse Strategies in RAP

- **Production center reuse**
 - There exists an independent development organization for Domain Engineering.
 - The domain infrastructure captures much of the domain knowledge in an integrated set of assets.
 - Application projects use the infrastructure following predefined process guidelines.
 - The domain infrastructure enables the organization to stay in business and be competitive.



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Main characteristics of Production Center Reuse strategy:






- The identification of the legacy products is undertaken by the DE office to determine the suitability of the legacy products within the domain. The identification is done within the domain and considering future needs of the domain.
- Domain Engineering defines and applies standard policies for reusable assets documentation. Each reusable asset should include information about its functionality, examples of use, quality and usability information, history of its use, problems encountered in its use, general information such as creation date and creator, basically it must provide a customising guide for aiding in the use of reusable assets.
- This strategy considers the use of reusable assets and includes activities such as finding, selecting, modifying /specialising reusable assets, integrating and providing feedback for the reuse group. A new life cycle is introduced in the software development process.
- Management recognises that projects share a common base of domain expertise and reuse is the proper development strategy to pursue.





Reuse Strategies in RAP

- **Domain-driven reuse**
 - Domain Engineering is the organization's strategy to maximize benefits and create new business opportunities.
 - Application projects are mechanically derived from the domain base infrastructure, enabling early validation of customer requirements.
 - Occasional deviations from the domain are managed in Domain Engineering and integrated in the common domain base.

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Main characteristics of Domain-Driven reuse strategy:


- The identification of the legacy products is undertaken by the DE office and is completely dependent on the domain defined and the future evolution of the market. Future markets and products are determined by their capacity to exploit reuse.
- Domain Engineering defines and applies standard policies for reusable assets documentation. Each reusable asset should include information about its functionality, examples of use, quality and usability information, history of its use, problems encountered in its use, general information such as creation date and creator.
- Application projects are mechanically derived from the domain base infrastructure using a reuse development methodology, enabling early validation of customer requirements.
- A formal analysis is performed among the projects and market to determine the business area(s) where reusable assets can add the greatest value.





Results

- The conducted analysis has checked the consistency of the three strategies with BAPO-A levels.
- Level 1 and 5 of BAPO-A have been identified as at a too low or too high level
- Levels 2, 3 and 4 have requirements that appear to be consistent with the three strategies proposed in RAP.
- This means that:
 - If a company implements successfully one of the three strategies, it can be considered at the respective BAPO-A level
 - Vice versa, if a company wants to achieve a certain level in BAPO, the correspondent reuse strategy can be used as a medium
 - Activities to carry on and selection criteria of RAP can give an overall picture of the effort needed to achieve a certain BAPO-A level.



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Levels 2, 3 and 4 have requirements that appear to be consistent with the three strategies proposed in RAP (see previous slides). This means that:

- If a company implements successfully one of the three strategies, it can be considered at the respective BAPO-A level.
- Vice versa, if a company wants to achieve a certain level in BAPO, the correspondent reuse strategy can be used as a medium.
- Activities to carry on and selection criteria of RAP can give an overall picture of the effort needed to achieve a certain BAPO-A level.



Results

- Selection criteria are used to select the appropriate strategy for companies' needs
- Desired BAPO-A level can be a new selection criteria vs. strategy implementation requirements
- They can be symmetrically used to evaluate the achieved BAPO-A level

	Project-based reuse (BAPO-A Level 2)	Production center reuse (BAPO-A Level 3)	Domain driven reuse (BAPO-A Level 4)
Horizontal domain	OK	OK	NOK
Unstable domain	OK	OK	NOK
Organizational attitude to risk	OK	Risk taker / Risk indifferent	Risk taker
Management commitment	OK	High	High
Good attitude to change	Programmers	Middle and high management	Middle and high management
Application products could share	Some reusable assets	Several reusable assets	Reusable core of assets
Experience of the personnel in the domain	Medium/High	High	High

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The table shows how, according to the characteristics of each organisation, it is possible to select the best reuse strategy.

In particular for each aspect of the organisation (attitude to risk, experience of personnel, kind of domain, etc.) it shows whether a particular RAP strategy is adequate or not. If the aspect is neutral with respect to a particular strategy, it indicates the level of commitment required to go for a particular strategy.



Conclusion & Outlook

- RAP strategies needed activities

	Project-based reuse (BAPO-A Level 2)	Production center reuse (BAPO-A Level 3)	Domain driven reuse (BAPO-A Level 4)
Gain management commitment and support	X	X	X
Define a cost mechanism among projects	X		
Establish good communication channels among projects	X		
Identify roles and responsibilities	X	X	X
Define the structure of the organization	X	X	X
Establish good communication mechanism between application projects and domain engineering		X	X

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Once the reuse strategy to implement has been selected, a certain number of steps must be moved in order to implement it.

The table shows (some of) the actions that a company has to take to implement each reuse strategy.



A Rational Product Family Architecture Roadmapping Process

Authors (alphabetical order by family name):
Jacco Wesselius (Philips)

A more detailed description of the contribution can be found in the book chapter "A Rational Product Family Architecture Roadmapping Process" by the same author, on which this text is based.

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Abstract

In this contribution, a framework for creating an architectural roadmap for product families is presented. The framework focuses on optimizing the economical results of architectural investments. Based on NPV-calculations in combination with scenarios based architecting, the economical value of architectural investment scenarios is determined. The process described in this paper is an idealized process: if it would be possible to do things based on complete information and in a completely rational way, the process would be a good way to define the architecture roadmap. In cases where information is missing (which is always the case when thinking about the future) or when decisions are not always made in a completely rational manner, the framework provides a nice outline for structuring intuition and uncertainty, which is useful to get hold of the process and to make sure that the outcome is at least partly rational.

Relation with other tasks / previous projects

* This work is related to "Linking Business Strategy to Architectural Decisions" by Eelco Rommes (Philips Research) in the same Families task.

Book chapter

An elaborate description of the work has been submitted to be a book chapter in the 'research book' edited by Timo Kakola and Juan Carlos Duenas.



Problem Introduction

Developing a product family requires high investments *early on*, anticipating returns *in the future* by cost reduction and / or value creation. Planning for the product family should be done in the context of the future.

The challenge of product family development is to walk the thin line between investing in the future and making profit today. That is, to balance between two extremes:

- *reuse-fetishism* occurs when reuse is seen as a guaranteed cost-savers, resulting in overly optimistic investments in product family engineering that cannot be economically justified.
- *platform skepticism* occurs when the initial high investments of product family development lead to a fear of uncontrolled cost growth: all investments that do not deliver immediate payback are pruned from product development proposals.

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Product Family development is costly. Initial investments in a product family architecture are high and need economical justification. The economical justification for product family architecture development is always based on *future* cost reduction or *future* value creation. This means that product family architecture planning needs to be done in the context of expectations and assumptions about future developments: How do we expect the future to be? How should the product family architecture evolve in order to maximize its benefits? What is the business case for product family development?

Many pitfalls can be identified from this perspective. A well-known pitfall is “re-use fetishism”: the belief that re-use is a guaranteed cost-saver, resulting in investments in product family architecture that cannot be economically justified. A similar thing happens when an organization cannot deal with the uncertainty associated with forecasting the future. To be prepared for everything, the scope of the product family architecture will be expanded, again resulting in unjustifiable initial investments, or even in complete project failure due to the resulting complexity (of requirements, design, organization, processes, etc).

In response to these pitfalls, re-use and platform skepticism may be borne. In fear of uncontrolled growth of the cost of the family architecture, all investments that do not result in immediate payback will be pruned from product development proposals. The challenge of product family development is to walk the thin line between dissipation of development resources in developing family architecture features that will never be used on the one hand and shortsighted skepticism on the other hand.



Product Family Architecture Pitfalls

There are pitfalls that result in unjustified initial investments:

- **Lacking a clear vision:**
 - Main value drivers are not known or tend to change frequently.
 - Priorities change quickly and often.
- **Being prepared for everything:**
 - Trying to get it perfect the first time.
 - Supporting too many products, too many features: too much variation.
 - Hidden assumption: the world will remain the same until we are ready for it to change.
- **Being prepared for the wrong things:**
 - Simplistic view of the future. („Current trends will continue as today.“)
 - Lots of implicit decisions.
 - Little communication between platform development and product development.

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Developing a product family architecture means making early investments in order to save money in future product developments. When thinking about product family architecture development, there are pitfalls that result in initial investments that cannot be economically justified.

• **Being prepared for everything**

It is important to realize that it is not affordable to be prepared for everything. What's more, since the future is unknown, it is impossible to be prepared for everything; by the time the complete and perfect product family architecture has been implemented, market values have changed, rendering the architecture imperfect after all...


Don't be prepared for everything. Be prepared for probable and important things only. But, ... what is probable? And what is important? These are the important questions when planning the evolution of a product family architecture. The framework presented in this paper pays attention to these questions.

• **Being prepared for the wrong things**

If you take care that the scope of the architecture is not too wide, you are not safe yet. Decisions to limit the scope have to be based on assumptions about the future of the product family. If these decisions are not made carefully, investments will be made in architectural features that will never be used. Or, even worse, architectural features may be developed that conflict with future product requirements. An important factor in relation to this pitfall is the "distance" between product family architecture (platform) development and the market/customer. If platform development is separated from product development, the distance between the two may become too large to bridge. Special attention needs to be paid to communication throughout the entire development value chain to avoid this.

• **Lacking a clear vision and decision making**

The main value drivers for an organization should be well known and relatively stable. The value of investments in architectural features can be expressed in terms of these value drivers.







Avoiding the Pitfalls: A Framework for Rational Roadmapping

To avoid these pitfalls, one should:

- Explicitly evaluate the costs and benefits of investing in the product family architecture.
- Take the future into account while doing so.

This contribution presents a framework for doing this.



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In general, one can say that due to incorrect evaluation of the costs and benefits of investments in the product family architecture, effort will be spent on the wrong issues, and initial product introduction will be delayed due to having to complete the implementation of the product family architecture (platform) first.



Modeling the Value of Architecture Investments

An architectural scenario is a sequence of relevant events:

- Investments: a negative cash flow at a certain point in time. Cost savings are represented by reduced investments for product development later in time.
- Income: a positive cash flow resulting from business value of developed products at a certain point in time.
- Discount rate: compensates the reduced value of future investments and income (due to interest, inflation, risk, etc.)

From these elements, the Net Present Value (NPV) of a scenario can be calculated.

But: the value of an investment can only be judged in view of assumptions about the future. The value of an architecture scenario therefore depends on other scenarios about the future: developments in market, application domain, and technology. These are called *strategic scenarios*.

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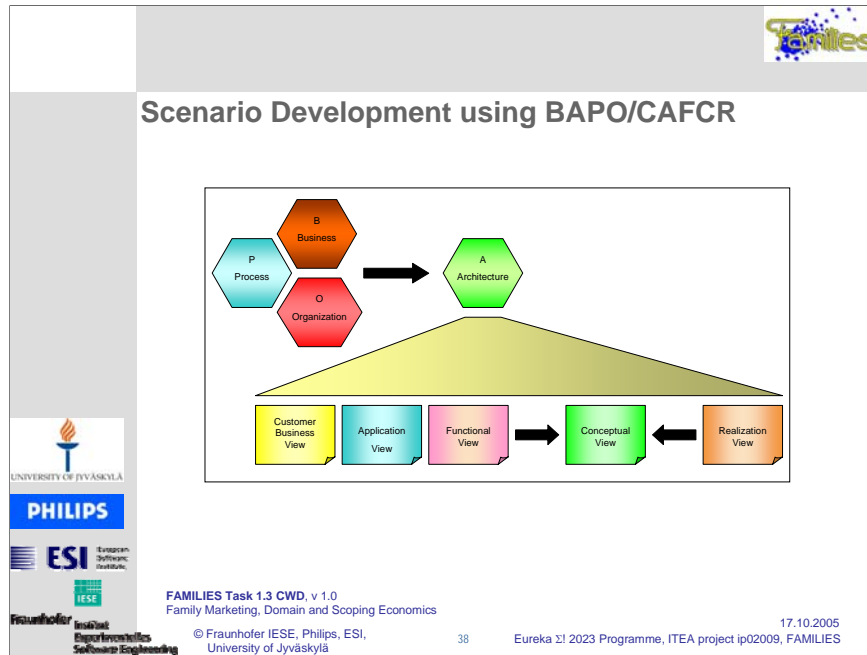
For different strategic scenarios the value of an architectural scenario will be different:

- If an architectural scenario creates value by enabling easy development of certain features, the value of the architectural scenario is high in strategic scenarios that predict a high business value for these features.
- If the enabled features prove to have no business value, the value of the architectural scenario will prove low.

This means that it is useful to value architectural investment scenarios against a set of strategic scenarios. For each of these strategic scenarios, the probability of occurrence needs to be estimated.

In the end, estimating the expected income and the investments needed to generate this income is a business judgment; one cannot expect a magic formula to determine this value. The way to evaluate value of architectural scenarios would be:

1. Draw up the architectural scenarios
2. Draw up the most important strategic scenarios
3. Estimate the investments needed to realize the architectural scenarios
4. Estimate the expected income for each architectural scenario for each strategic scenario.



The BAPO/CAFCR framework is very well suited for scenario development (see the results from the Scenario Based Architecting project at Philips Research and Philips Medical Systems [2]). Each view in the model can be used to create scenarios relevant for the evaluation of architectural investment scenarios. An overview of the process is:

- **Business, Process and Organization** scenarios are created.
 - oWhat are the business drivers?
 - oWhat is expected to happen to the organization over time? Will it grow? Will it be spread over various geographic locations? Will other companies be acquired that bring new skills?
 - oWill processes change to fit with new organizational structures?
- **Customer** scenarios and **Application** scenarios define which products and or product features will have value to the customer:
 - oWhich are the main value drivers?
 - oHow will the products be used in the customers' processes?
 - oWhat will be the most important product features for the users? What will be the characteristics of the product's users?
 - oAnd how will their relevance and definition evolve over time?
- **Functional** scenarios will identify which functions and features the system of the product will be required in the future.
- **Technology** scenarios address (as part of the **Realization** view) new technologies that enable new value creation and obsolescence issues for technologies that are currently in use:
 - Which technological opportunities will emerge?
 - Will these contribute to the business drivers?
 - Can they be related to the value drivers?
 - When will technologies used today be obsolete?

In the end, the question for each of these scenarios will be:

- How likely is the scenario to occur?
- What will the impact of the occurrence of the scenario be on the business? Can the impact be translated into financial value (and subsequently into NPV)?

Now, a selection of important scenarios can be made. Based on these strategic scenarios, a set of architectural investment scenarios can be evaluated: how well would a defined evolution of a product family architecture be aligned with the selected strategic scenarios? And based on the answer to that question: what is the expected value of the architectural investment scenario? Could delaying part of the investment increase the expected value? Or would it be wise to increase the initial investments?



Cost Saving and Value Creation Opportunities

Essential in creating a product family business case is estimating the value of the developed product family. Much of the analysis is domain specific, but there are aspects that are worth considering in many cases:

- Time to market
- Development efficiency
- Cross-product compatibility
- Product upgrading
- Product manufacturing costs
- Lifecycle management costs

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Time to Market

An important consideration with respect to reduced time to market due to product family development is the likelihood of new products being developed with a short development lead-time. When the picture of future new product (features) is not clear, the likelihood that the extensibility of the product family architecture meets future customer demands is low. Business scenarios are essential: which types of products are expected to be valuable in future? In which areas do investments in family extensibility make sense from a business point of view?

Development Efficiency

If a series of products is developed reusing a large set of components, development efficiency is expected to go up: functions and features need to be developed only once, and cost of quality is expected to go down. But to achieve this, a clear picture of a series of products to be developed as part of the product family is needed. Which assets will be reused? Which features of these assets are relevant for the foreseen reuse? Knowing the products to be developed based on the reusable assets will greatly improve the reusability of the components and limit the investments in reusability.

Cross-product compatibility

Depending on the type of business and the type of product being developed, compatibility among systems can be an important feature of a product portfolio. If products are based on different architectures, maintaining compatibility among products can be a major headache. Developing a portfolio of products based on a common product family architecture can reduce the compatibility problems significantly. Products based on the same architecture will share a set of interfaces and a set of operational conditions that will bring a certain level of compatibility. If products share the same implementation of the interfaces, compatibility among these products can come at relatively low cost.

Product upgrading

If subsequent products are based on a single product family architecture, developing upgrades for the installed base can be expected to require far less development efforts than the situation in which subsequent products are based on completely different product architectures. This requires well-planned evolution of the product family architecture: a generation break can be killing for product upgradeability.


Product Manufacturing Costs

If a product portfolio is based on a product family architecture, the products will likely share a large set of components. If these components are hardware components, this may facilitate optimizing the logistic and manufacturing chain.

Life Cycle Management Costs

If products are based on the same product family architecture, solutions for problems may be shared by all products based on the same architecture. If products are based on the shared architecture, servicing procedures and tools for these products in the field can be similar. This will enhance the efficiency of the service departments, and it can reduce investments needed for training the service task force. If products are based on a set of shared hardware components, the costs of keeping spare parts on stock can be reduced significantly.






Theory vs. Practice

In theory, a spreadsheet is enough to do the job. In practice, you need more than that:

<ul style="list-style-type: none"> • Which strategic scenarios to consider? • How to estimate the income? • What are interesting architectural options? • Which architectural options to consider? • Which technology options to consider? • How to estimate the investment? 	<ul style="list-style-type: none"> • business overview and intuition • business experience and market intuition • architectural skills • architectural experience and intuition • technology overview and intuition • architectural/development experience (potentially supported by metrics and historic data)
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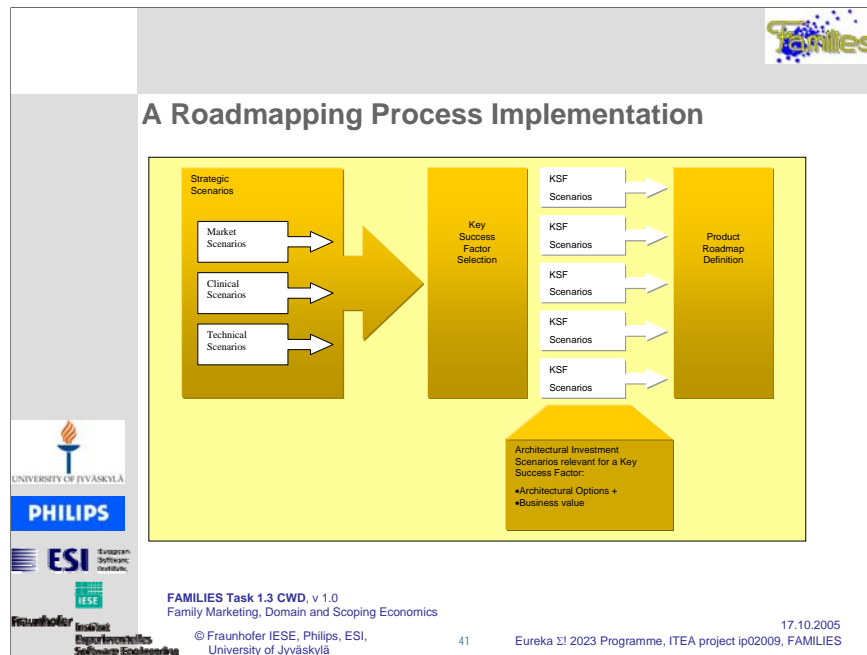
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Looking at the framework discussed above, one might think that anyone with a pocket calculator (or even better a spreadsheet) can do the job. Is it really the case, that the optimal architectural investments can be selected with a set of simple formulas?

No, selecting the optimal architectural investments is a difficult process that requires architectural skills and experience, intuition, business overview and, above all, the courage to deal with uncertainty: make your assumptions about the future explicit, at the risk of having been wrong...

The major challenge in applying the architectural roadmapping framework discussed in this paper is to limit yourself: it is impossible to consider every interesting strategic scenario, or every architectural investment scenario. The amount of combinations would be overwhelming. To be able to get results, it is essential to make a selection.

For many steps in the process the experience, skills and intuition of a multi-disciplinary group of people is needed: business managers, product managers, application specialists, (clinical) scientists, technology experts, architects, etc.



In the implementation of the process in the Business Unit CardioVascular of Philips Medical Systems, we have organized ourselves to get most from the multi-disciplinary approach:

- Each discipline creates its own pictures of the future (clinical science, marketing, technology, ...). This is a mono-disciplinary activity, but cross-disciplinary communication is encouraged to get most out of the activities.
- Based on this, a set of *Key Success Factors* is defined in the Strategic Plan: in which aspects does the business unit want to excel? Where do we want to add value? These Key Success Factors form the stable basis for longer-term roadmap definition. They do not tend to change overnight and therefore provide the required constancy.
- For the selected Key Success Factors, a multi-disciplinary team is assigned to combine the knowledge and experience from multiple disciplines into investment scenarios: what should we do to further excel in a specific Key Success Factor. What would the required investments and the expected income be?
- The output from the KSF-teams form the architectural scenarios that are input to the roadmap definition process, where the planned products (and their features) are plotted on a time line, together with the required (architectural) investments. This is the activity where the NPV is optimized. Again, this is done in a multi-disciplinary team.

In addition to the KSF-view, a technology/component view on the product family roadmap is created. For the main building blocks of the system (e.g., x-ray tubes, x-ray detectors, image processors, patient tables, C-arms, etc.) roadmap scenarios are developed. For each sub-system a roadmap team will identify opportunities for improvement. These teams will relate the technical improvement opportunities in the main system components to the Key Success Factors: what will the impact of investments in the sub-system on each KSF be? Based on the information from the KSF view, and the information from the sub-system view, the final selection of products and the associated investments in technology and product family architecture are made. By explicitly relating component characteristics to business value, we try to stimulate business communication throughout the entire development value chain.



Conclusions

Product family roadmapping requires:

- Making value and cost of architecture investments explicit.
- Taking into account that future value is worth less than value generated today (NPV calculations.)
- Evaluating investments to their possible future returns by means of strategic scenarios.

Any roadmapping process will have to be adapted to suit specific business needs at specific times. This contribution describes a framework for designing and using such processes.

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The main elements of the proposed roadmapping approach are:

1. Making the value and cost of architectural investments explicit.
2. Value generated in the future is worth less than value generated today (NPV-calculations).
3. A set of strategic scenarios is used to evaluate the likelihood of actually realizing the potential value of investments in the product family architecture.

A set of simple formulas shows how the value calculations associated with this approach can be done.

This offers a framework that identifies the aspects to be considered for product family architecture roadmapping. A complete implementation of this approach will prove impractical because of the overwhelming number of scenarios that are conceivable, and the explosion of the number of scenario combinations to be considered. The “art of roadmapping” consist of reducing the number of scenarios: only consider those that have the largest business impact. In practice, the execution of the roadmapping process will neither be linear, nor completely complete, nor completely rational.

In this, creating an architecture roadmap is not different from designing software or a system. The recommendations made by Parnas and Clements in [3] for a design process also apply to the architecture roadmapping process: having a rational process in mind will steer the process by identifying the issues to be considered and their dependencies. As such, it will improve the execution of the roadmapping activities in practice, and define a framework for structuring the deliverables.

[1] Klaus Schmid, *A Quantitative Model of the Value of Architecture in Product Line Adoption*, in: Frank van der Linden, ed.: PFE-5: Fifth International Workshop on Product Family Engineering, Siena, Italy, November 4-6 2003, Springer, LNCS.

[2] Pierre America, Dieter Hammer, Murugel T. Ionita, Henk Obbink, Eelco Rommes, *Scenario-Based Decision for Architectural Variability in Product Families*, accepted for SPLC 2004: Third Software Product Line Conference, Boston, MA, USA, August 30-September 2, 2004

[3] David L.Parnas and Paul C.Clements, *A Rational Design Process: how and why to fake it*, IEEE Transactions on Software Engineering, 19(2):251-257, February 2003



Linking Business Strategy to Architectural Decisions

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A more detailed description of the contribution can be found in the book chapter "Scenario-Based Architecting: Harmonizing Short and Long Term Business Needs" by the same authors, on which this text is based.

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Abstract

Architecting is at the core of system family engineering. The architecture of a system family determines how products are derived efficiently from the core assets. Adapting an architecture can be challenging, and implementing a change costly. Especially when the change was unforeseen, it is most likely that the architecture is not fit for it, making the matter expensive.

We present a scenario-based architecting method that makes plausible architecture choices explicit and allows assessing them in light of short and long-term goals. The result is a set of candidate architectures together with (estimates of) their properties and how well they fit in the long-term future.

Relation with other tasks / previous projects

* This work is related to "A Rational Product Family Architecture Roadmapping Process" by Jacco Wesselius (Philips Medical Systems) in the same Families task.

* The work described here is an extension of the work done in CAFE / WP 1 / Task 2 : „ Scoping for multiple domains and product populations" by Eelco Rommes (Philips Research)

Book chapter

An elaborate description of the work has been submitted to be a book chapter in the 'research book' edited by Timo Kakola and Juan Carlos Duenas, under the title "Scenario-Based Architecting: Harmonizing Short and Long Term Business Needs" by the same authors.



Problem Introduction

A system family architecture must support the derivation of several, possibly many, different products.
The architecture must deal with *variation* to support the scope of the system family.

Problem: things change.
Changed business needs lead to desired new features, products, domains, etc.

Adapting an architecture can be challenging.
Implementing a change can be costly.

We want long-living architectures that can cope with change. We need an architecting process to support that.

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Architecting is at the core of system family engineering. The architecture of a system family determines how products are derived efficiently from the core assets. To allow the derivation of many different products, a system family architecture has to deal with variation. The architecture's support for variation pins down the scope of the system family. Too much variation will make the architecture overly complicated. Such an architecture is likely to be expensive to design, implement, and maintain. Support for too little variation results in a limited scope, and may mean losing out on business opportunities.


To complicate matters further, the optimal scope of a system family is not fixed in time. As times change, so do the needs of a business, and the demands on its system families. New features will be introduced, abundant ones removed, neighbouring domains may be entered or new products added to well-known domains. Advances in technology may offer opportunities to enhance the system family. These are just a few examples of changes that lead to new requirements for the architecture to support. The architecture must evolve to support efficient derivation of new or improved products.

But adapting an architecture can be challenging, and implementing a change costly. Especially when the change was unforeseen, it is most likely that the architecture is not fit for it, making the matter expensive. At some point, it is cheaper to throw away the architecture and start a new system family than to change the existing architecture. A primary goal of scenario-based architecting (SBA) is to delay this point by keeping system derivation in the right scope cheap and efficient. To reach this goal, the method seeks to minimize the need for change and to make necessary changes simple.

Architects minimize the need for change by making sure that the architecture supports the right scope at the right time. They may make change easier by making the architecture flexible in ways that seem needed in the near future, and by making sure that the architecture is evolving in a direction that will allow them to keep it flexible in the long run. Changes made to the architecture to meet today's needs may be obstacles when it needs to be adapted again next week, causing a premature end of life for the architecture. Still, no architecture that is not profitable today will even reach next week. Architects must balance the short and long-term needs when designing a system family architecture.

From what we have seen in practice, architects do such balancing exercises implicitly. For each reason to change, there will be numerous ways to adapt the architecture. Each of these will have its own specific consequences in both the short and long run. An architect may swiftly dismiss the majority of options and choose to pursue just a handful, based on his intuition and experience. However, intuition and experience are not always right, and in any case they are hard to communicate to other. An explicit overview of available options along with their consequences helps to make decisions that suit the short as well as the long-term business goals.






Scenario-Based Architecting

Scenario-Based Architecting (SBA) is an architecting method that takes short- and long-term future requirements into account.

SBA makes plausible architecture choices explicit and allows the assessment of these choices.

The method results in a *family of architectures* together with (estimates of) their properties and how well they fit the long-term future.



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We present a scenario-based architecting method that makes plausible architecture choices explicit and allows assessing them in light of short and long-term goals. The result is a set of candidate architectures together with (estimates of) their properties and how well they fit the long-term future.

Of course, the meaning of 'long-term future' is relative. In the domain of medical imaging systems the long-term future is ten to fifteen years away. For a producer of mobile phones, the long-term future may be four to five years away. And in the highly dynamic world of e-commerce, long-term may be next month. In any case, things will change in unforeseen ways between today and the long-term future. Scenario-based architecting provides a way to deal with this.




Case Study: Integrating the Cathlab

The catheterization laboratory (cathlab) is a hospital room for diagnosing and treating heart and vessel related diseases.

The cardiologist navigates a catheter inside the patient's vessels to:

- Insert contrast fluid for making images through an X-ray device,
- Repair vessels, e.g., by opening blockages.

There are many devices in the cathlab that should work together for effective and efficient treatment and diagnosis.



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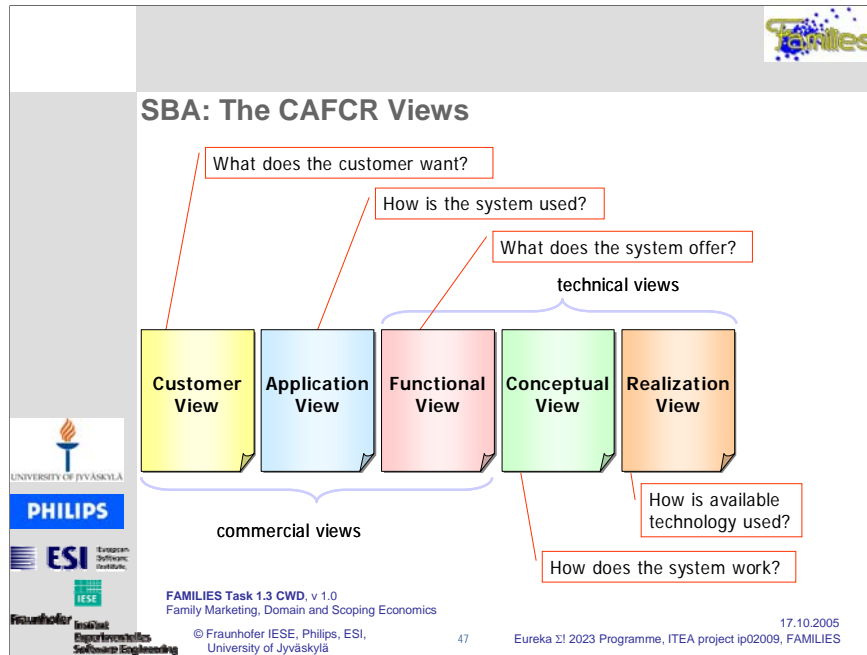
The catheterization laboratory (cathlab) is a hospital room where patients with vascular disease may be diagnosed and/or treated. One of the most common forms of such diseases occurs when an artery is narrowed by plaque, limiting the amount of blood that flows through it. Part of the body is then deprived of access to fresh blood, which may cause a heart attack if the artery leads to the heart, or stroke if it supplies the brain.

One way to treat this disease is by opening the blockage from the inside. The physician enters a catheter in an artery near the patient's loin, and gently moves it to the desired location. The tip of the catheter holds a tiny balloon that is inflated to push the plaque to the sides, opening the artery and allowing a restored flow of blood. Optionally, a small mesh wired tube can be placed to refrain the artery from re-closing after some time. A tube like that is called a stent.

The cathlab offers equipment to support these and other catheterization procedures. A central role in the cathlab is fulfilled by a cardiovascular X-ray system. Among others, this system is used to visualize the patient's vessel structure and the exact location of the catheter therein. Since vessels do not scatter X-rays, the cardiologist injects contrast fluid through the catheter. This contrast fluid makes it possible to detect the vessel structure and possible problems such as blocked arteries. High quality images can be used to do measurements regarding the blockage. Examples are the blood flow through the blockage, its length and width.

In other applications, catheters may directly interact with the heart itself. Another variation is the treatment of children, who have smaller blood circulation systems and faster heartbeats. To minimize the amount of contrast fluid and scattered radiation that a child is exposed to, two detectors may be used simultaneously. These and other variations are addressed by different members of the system family.

Many other devices populate the cathlab besides the X-ray imaging modality. There are monitoring devices for electrocardiograms (ECG) and blood flow (hemodynamics), reporting and archiving applications. Sometimes intravascular imaging systems are used to visualize the insides of an artery. Another way of obtaining new and more precise information is to use three-dimensional images. These images can either be created on the spot or taken from diagnostic procedures that the patient has undergone earlier, for example using magnetic resonance imaging. In the latter case, we talk about 'multi-modality' procedures, because information from different types of imaging systems is combined in one procedure. Creating three-dimensional models from the two-dimensional X-ray images can be done by an application called three-dimensional rotational angiography (3DRA). In this application, many images are created from many different angles, after which these images are combined into a single three-dimensional model.



The customer view captures our knowledge of the customer. We define customer as the party that makes the final decision to buy our system. This may be a person, or a group of persons. The customer may or may not be a user of our system.

In the application view we study how the systems that we are architecting can be used to fulfill the customer's needs.

This view is used to describe the externally perceivable properties of the system under development, in a concise way. Where such a property indicates the presence of a certain piece of functionality, we typically call it a feature. Other properties are typically called qualities.

The description (not the content) of the functional view tries to be as independent as reasonably possible from the way the system is used or the way it is implemented. In this respect, the functional view can be seen as an interface between the customer and application views on the one hand and the conceptual and realization views on the other hand.

The goal of this view is to describe the essential concepts that govern how the system works.

The realization view describes how the system is realized using available technologies.



SBA: Method overview

SBA is iterative. An iteration has three core steps:

1. Explore variation,
2. Create architecture scenarios,
3. Assess scenarios.

In earlier iterations, more effort is spent on the commercial views of CAFCR (CAF).

In later iterations, the focus shifts to the technical views (FCR).

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Strategic scenarios

Strategic scenarios are descriptions of plausible long-term futures in the world at large. They are typically the result of a multi-disciplinary study into the business domain that takes business, technical, application and organization trends into account. In SBA, strategic scenarios are input to the iterations. They are used to guide decisions and to assess the resulting candidate architectures.

Explore variation

The first step is to explore the architecture options. This is done by modeling variation in all five CAFCR views. The resulting variation models can guide further decision-making and document the options that were considered.

Create scenarios

Since it is impossible to assess each possible architecture, the variation models are used to create a set of architecture scenarios. There are three to five scenarios for each view. Together, these scenarios describe candidate architectures for a system family.

The scenarios capture a wealth of knowledge in a very concise way. This enables architects to travel light: it is easy to experiment by creating a few scenarios, examining them and rejecting them if the results are not up to par. For some scenarios, more tangible information is needed, for example to explain them better to stakeholders, to document them for future reference or to facilitate their assessment. To this end, *extended scenarios* can be used. Adding information to an architecture scenario can easily create an extended scenario. Such information typically consists of temporal information or extra context. In SBA, extended scenarios are used to enhance the means of assessment. Examples of extended scenarios are customer profiles in the customer view, and collaboration diagrams in the conceptual view.

Assess scenarios

The next step is to assess the architecture scenarios for their quality properties. The method allows for the assessment of many different qualities. We have assessed scenarios for such diverse qualities as usability, performance, product value, and cost of use [5,21]. We have used both quantitative and qualitative approaches for such assessments. Here, we show examples of both types of approaches.

Moreover, the architectures are evaluated for their future-proofness by describing for each architecture scenario how well it fits the futures represented by the strategic scenarios. The result is a set of plausible candidates for our system family architecture, together with assessment results showing their properties for a number of quality attributes and how well they fit a set of possible futures.

Adapt architecture

The last step is to modify the system family architecture according to our needs. The candidate architectures and their assessments provide us with ample input to complete this step. Adapting the final architecture means we should document the architecture in full detail. We do this by creating a number of architecture artifacts. Each artifact shows a different aspect of the system under development. Together, the views and their artifacts sketch a more or less complete picture of the problem and solution domains.



Strategic Scenarios

The future is uncertain. Therefore, we consider a number of scenarios that describe possible developments of the world in the future.

These *strategic scenarios* concentrate on the aspect of the world that is relevant to our business, in our case study: the world of healthcare.

Creating strategic scenarios requires a multidisciplinary team of:

- Business strategy experts,
- Application domain experts,
- Technical experts,
- Management.

HIGH technological advancement	<p>See Treat Cure</p> <p><i>Hospitals and clinics offer efficient care at reasonable quality</i></p>	<p>Brave New Pharma World</p> <p><i>Economy spurs biomedical breakthroughs that enable personalized treatment for everyone</i></p>
LOW technological advancement	<p>McHealth</p> <p><i>Fastfood-like clinics maximize patient throughput while offering 'good enough' care</i></p>	<p>Clinique de Luxe</p> <p><i>Wealthy, empowered patients demand state-of-the-art care and comfort</i></p>
LOW economic growth	<p>© Fraunhofer IESE, Philips, ESI, University of Jyväskylä</p>	
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The changes to the requirements that will occur in the future are very uncertain. Therefore we consider a number of scenarios that describe the possible developments of the world in the future, along the lines of the work of Schwartz [1]. These scenarios concentrate on the aspect of the world that is relevant for our field of business. In our case study, this would be the area of healthcare for cardiac patients. Such scenarios form a good basis for business decisions, and therefore we call them strategic scenarios. A useful way to communicate these scenarios is using cover stories: fake magazine articles describing the world of the scenario in natural language.

A pitfall in reasoning about the future that should be avoided is to choose a single 'official future'. It may be the result of wishful thinking, or of simply extrapolating observed trends. Choosing a single 'future' as the most likely is harmful because it means we close our eyes for all the opportunities and threats that are outside of this official vision. To harness ourselves against this risk, we use multiple strategic scenarios as input. Four seems to be a good number. Two scenarios are not enough to span a wide range of possibilities, and creating three scenarios holds the risk of creating a 'low', 'middle' and 'high' scenarios, after which the middle one is likely to (implicitly) achieve the dreaded 'official future' label, a situation that we were trying to avoid.

In SBA, strategic scenarios are used as input to the architecting process. They provide the necessary knowledge of business context to create both variation models and architecture scenarios, and are used as test cases to assess candidate architectures for their business value in the long-term future.

Disclaimer: Since strategic scenarios inherently contain business sensitive information, we will not show existing ones here. We have come up with four placeholders instead, that serve to illustrate the use of strategic scenarios in SBA. These placeholders are much more simplistic than their real-world counterparts, and each varies only two dimensions: economic growth and technological advancement in healthcare. The titles were based on publicly available commercial presentations.



Explore variation

The goal of this step is to explore the space of possible architectural choices. We do so by creating a *variation model* for each of the CAFCR views.

Each model captures the variation in its view:

- The *customer* variation model expresses the market segmentation that underlies the design of the product portfolio.
- The *application* variation model captures activities performed by a user in interaction with the systems in the family.
- The *functional* variation model shows the possible features of the systems and one can choose between them.
- The *conceptual* variation model explores the possible concepts supporting the system family architecture.
- The *realization* variation model focuses on the different ways of mapping architectural concepts onto available technology.

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The goal of this step is to explore the space of possible architectural choices. To do this, the construction of a model can be of help in several ways:

1. *To structurally explore the variation space in the various views, and the relationships between them.*

By modeling the variation space, we quickly get a feeling of the complexity and main issues in the domain. It is relatively easy to spot gaps in a model, ensuring that the variation space will be explored thoroughly. The flipside of the coin is that models tend to get very large. It is essential to be practical in this respect and not to try to include everything in the domain.

Relationships between choices in one view and the other can be shown by means of repeating elements in both views.

2. *To guide and document the choices that were made, as well as the options that were disregarded.*

The resulting models can be used to guide decisions. Which core features will the system architecture support? What kinds of application? In the next step, we will use the models to make these choices and capture them in the form of scenarios. The original models contain the full range of possibilities that were considered, including the options that were not chosen. This can help to avoid endless reconsidering of the same options.

3. *To enhance communication and raise awareness about these choices between the architecture's stakeholders.*

Although creating the models demands that one is accustomed to working with abstract models, the notation used is partly chosen for its simplicity. In our experience, the resulting models are simple enough to be understood by people without a background in modeling too. This allows stakeholders other than the architect to contribute to the models by reviewing or in some cases even co-creating them. For example, marketers or sales people could be co-authors of the customer variation model. At least, they can read the model to verify that their input was interpreted correctly.

Sources of input for this step are the strategic scenarios, roadmaps, design documents, requirements, and of course the tacit knowledge of (company) experts.

The exploration step results in a variation model for each view. These models are connected by repeating elements, allowing us to reason across the CAFCR views. This step allows us to explore many possible architectures simultaneously, without pinning down definite choices.

Although we describe a separate model for each of the CAFCR views for practical reasons here, these models are actually interconnected. To achieve this we allow relations between elements from adjacent views, where the direction of the relationship follows the order of the CAFCR views. In our example models, we will only show a few of these cross-view relations. In these cases, the elements that are repeated from another view's model contain a small letter indicating their originating view.



Create Architecture Scenarios

In each of the variation models, we can select a set of architecture scenarios that covers (most of) the model. These architecture scenarios should be:

- **Consistent**, with the model's semantics,
- **Reasonable**, in that the choices are well-balanced,
- **Interesting**, so they will teach the architect something new when the scenarios are assessed,
- **Spanning**: the total set of scenarios should cover a large part of the variation space.

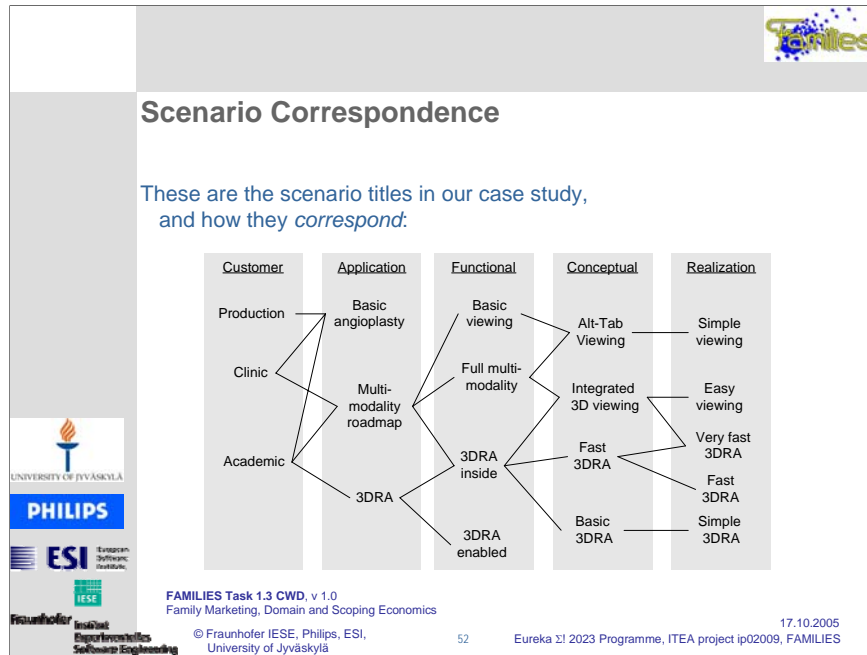
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Where the variation models describe the variation space, the scenarios define a few individual points in this space, which we consider for further analysis. Each architecture scenario describes the architecture from a single viewpoint. Such an architecture scenario consists of a single set of choices in the view's variation model. For example, an architecture scenario in the customer view will typically describe a market segment or a type of customer. Scenarios in the conceptual view on the other hand, will document a possible conceptual design for our system family architecture. Architecture scenarios should satisfy a few criteria:

- The set of choices that defines the scenario should be **consistent** with the view's variation model semantics.
- A scenario should be **reasonable**, meaning that the set of choices as a whole should show a certain balance. It would not be reasonable to omit a basic feature from a high-end system. Although technically this would be possible, the scenario would not be very reasonable.
- A scenario should be **interesting** to us. The next step will be to assess the scenarios, and it makes no sense to put effort into scenarios that we plan to disregard anyway.
-
- The total set of scenarios should **span a large part of the variation space**. This means that they should be sufficiently different from each other. In our experience, about three to five architecture scenarios per view are sufficient.



We allow two scenarios in different views to correspond to each other when they describe choices that are consistent across the views, according to the cross-view relationships of the variation models. We use this rule to choose pairs of corresponding scenarios. For example, when we look at the correspondence between application and customer scenarios, we reason about the way a given customer would perform the angioplasty procedure that we have modelled in the variation view. An academic hospital is likely to use more advanced, state-of-the-art functionality, while a high volume production site will use the well-known more basic features.

When we want to find conceptual scenarios that correspond to a functional scenario, we will look at the features of the functional scenario and choose conceptual scenarios that provide concepts to implement all those features. This way we are sure that the conceptual scenario correctly supports the functional scenario.

Scenario correspondence is important in the next step of the method, when we will need it to group scenarios into coherent wholes which we can assess and compare.

The total set of scenarios and their corresponding relations form a family of candidate architectures. Particular instantiations can be derived using the correspondence relations. A candidate architecture is a set of five corresponding scenarios that together describes the architecture using the CAFCR views. In the scenario graph shown here, there are twenty-three complete paths from customer to realization scenarios. Each of these paths represents a single unique candidate architecture.

Candidate architectures that differ in their commercial scenarios, but share the same conceptual and realization scenarios, actually represent different systems that can be derived from a single family architecture.



Scenario Assessment

Assessment is the last step of an iteration.
We distinguish three basic types of assessment:

1. **Functional** assessment means checking whether or not a candidate architecture supports the required functionality.
2. **Quality** assessment means determining the property of an architecture for a quality attribute and comparing it to the required value.
3. **Strategic** assessment means determining how well a candidate architecture fits the (future) business needs.

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The last step of an iteration is to assess the architecture scenarios that we created. Our goal is to assess many plausible architectures at once, with relatively little effort. Now that we have constructed a family of candidate architectures, we are ready to do that. The assessment of software architectures for their quality requirements has been well described (e.g. chapter 5 of [2].) Many of such methods can be used in this step to assess the architecture scenarios. The difference is that in SBA, such assessment methods are applied to a *family* of candidate architectures.

The assessments will give us information about the expected quality properties of the architectures. They can also assure us that the desired functionality can be handled by the architectures or bring shortcomings to light. We can use this information to enhance the architecture scenarios in another iteration or, if the results are satisfactory, to adapt the system family architecture according to a chosen candidate architecture, after which the process ends.



Example: Quality Assessment

An example of assembled quality assessment results:

Quality attribute:	Candidate architecture:				Metric:
	CA1	CA2	CA3	...	
Treatment selection:	81	93	93	...	% the probability of a correct diagnosis.
Patient accessibility:	0	0.6	0	...	m ³ space occupied by equipment in a defined patient centred subspace
Frequency of use:	60	30	40	...	# percentage of interventions making use of at least one of the new features
Ease of use (avg):	42	55	52	...	mins the average total procedure time for a selected procedure
Ease of use (wc):	60	71	68	...	mins the worst case total procedure time for a selected procedure
Performance:	120	28	28	...	secs the time it takes to display a complete 3D model

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We have to make the quality attributes that we are interested in measurable. This is done by defining quality metrics. It is beneficial to define the metrics in a precise, quantitative way whenever possible, even if we know that the values will be based on experience or expert intuition alone. The main advantage is that it forces us to be as precise as possible in defining quality metrics. This can prevent misunderstanding and disagreement among the stakeholders on what is meant by a certain quality. Another advantage is that we can compare the results of the assessment to experiments on real systems. Either on existing systems if we are trying to improve a certain quality, or to the target system after it has been built.

A risk involved in defining the metrics is that metrics seldom completely reflect their underlying quality attributes, but nevertheless become goals by themselves. This may lead organizations to aspire for suboptimal results from the original quality attribute viewpoint.

The assessments will give values for the assessed quality attributes and their metrics. We assemble these values in a table showing the scores for each candidate architecture. Background colour or grey scales can be used to indicate especially good or bad properties. For some metrics, a lower score is better while for others a high score is better. The use of colours or grey scales enables us to get a quick indication of scores for each candidate architecture without studying the table in detail. In the example shown here, a lighter background indicates a more desirable property for the candidate architecture.



Adapt Architecture

This step consists of choosing a candidate architecture as the new system family architecture. To complete the step, this new architecture has to be documented properly.

To this end, the architectural views must be described using artifacts. In some cases, the artifacts directly correlate to an architecture scenario. We call such artifacts *extended scenarios*. Examples are:

- *Customer profiles* are natural language descriptions of a particular type of customer. They extend customer scenarios.
- *Collaboration diagrams* describe how components interact to achieve a goal. They extend conceptual scenarios. Also, they can be coupled to *use cases*, which may extend functional scenarios.

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If the assessment results are not satisfying, a new iteration can be started by going back to the explore variation step. We can extend the models with new options allowing us to create better architecture scenarios, or we can work on specific areas of the models in more detail to get more precise assessment results.

If the assessments do show satisfying results, we are ready to adapt our system family architecture. The goal of this step is to further document the candidate architecture of our choice. Partly, this documentation consists of the variation models, architecture scenarios, extended scenarios and assessment results. Supporting artifacts are created to document the candidate architecture in more detail. Such artifacts may or may not have been created already earlier in the process, for example to aid in assessments.

Examples of supporting artifacts are: customer key drivers, workflow models, feature dictionaries, and architectural styles.










Conclusion

Architectures, especially system family architectures, can be hard to change and costly to implement. They should be designed with future requirements in mind to make change easier and extend their profitable lifetime.

Therefore, both immediate and long-term business needs need to be taken into account when (re)designing an architecture.

Scenario-Based Architecting is a way to do that.

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A system family architecture represents a significant long-term investment. The ease with which the architecture can deal with scope changes such as new features, new products, and better quality properties has a large impact on the success of the system family. The design and subsequent evolution of the system family architecture determines its ability to adapt to new requirements. It is crucial that both the long and short-term future is taken into account when doing system family architecting. We have presented a scenario-based architecting method that supports the design and evolution of system family architectures taking the future into account. The method was successfully applied in several industrial case studies, involving a family of medical imaging systems.

Literature

- [1] P. Schwartz: *The Art of the Long View*. Doubleday, 1996.
- [2] J. Bosch: *Design and Use of Product Line Architectures*, Addison-Wesley, 2000.