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Using Business Capability Maps for Application Portfolio Complexity Management

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Zusammenfassung

Die Geschäftsmodelle zahlreicher Organisationen basieren auf Lösungen der Informationstechnologie (IT) und Praktiker implementieren zunehmend neue Anwendungen, um die Geschäftsanforderungen erfüllen zu können. Dies führt zu großen Anwendungsportfolios (AP), weiteren Abhängigkeiten zwischen Anwendungen und AP-Komplexität (APC). APC ist ein wichtiges Thema im Enterprise Architecture (EA) Management und Wissenschaftler sowie Praktiker haben in den letzten Jahren Komplexitätsindikatoren und ihre Zusammenhänge erforscht. Um Handlungsempfehlungen zur Reduktion der APC ableiten zu können, ist die Transparenz über APC-Indikatoren ein wichtiger Erfolgsfaktor — dabei fehlen Visualisierungen, die diese Transparenz liefern. Dem Konzept der Business Capability Map (BCM) wird in diesem Kontext eine hohe Bedeutung beigemessen. Unternehmensarchitekten nutzen die BCM zur Analyse, Planung und Überwachung von Business Capabilities und langfristigen Planung der EA.

Diese Arbeit beschäftigt sich mit der Frage, wie BCMs genutzt werden können, um die Transparenz von APC zu erhöhen. Das Kernartefakt dieser Arbeit ist eine Sammlung von 14 Visualisierungen, die Transparenz über APC aus verschiedenen Blickwinkeln und in Abhängigkeit von konkreten APC-Indikatoren erzeugen. Des Weiteren werden drei Kennzahlen zur APC-Messung und eine Softwarelösung zur Visualisierung entwickelt und evaluiert. Die Zusammenhänge zwischen der BCM und Applikationsinformationen und die Funktionsweise der Visualisierung werden in einem Konzept vorgestellt. Die Evaluierung der Artefakte zeigt, dass die Visualisierungen die Transparenz über APC erhöhen und konkrete Handlungsalternativen zur APC-Reduktion abgeleitet werden können.

Ausgehend von einer Literaturrecherche wird zu Beginn der Dissertation der Begriff APC definiert und bestehende Ordnungsrahmen für AP-Management (APM) zur Reduktion von APC analysiert. Diese Erkenntnisse werden genutzt, um ein Capability-basiertes Visualisierungskonzept zur Transparenzerhöhung von APC zu definieren. Das Konzept ist iterativ erarbeitet: Die erste Iteration hat das Ziel, APC zu messen, indem drei Kennzahlen definiert und die Resultate der Kennzahlen auf einer BCM visualisiert werden. Die Kennzahlen und Visualisierungen werden im Rahmen einer Fallstudie mit einem Automobilkonzern evaluiert. Die Resultate zeigen, dass die Nutzung der BCM als Visualisierungsmedium sinnvoll, die Kennzahlen zur APC-Messung jedoch ungeeignet sind. Ausgehend von dieser Erkenntnis, werden in einer zweiten Iteration 14 Capability-basierte Visualisierungen definiert, die jeweils Transparenz zu konkreten APC-Indikatoren erzeugen. Die Visualisierungen werden mit zwei EA-Experten aus zwei Organisationen definiert und durch Interviews mit 25 EA-Experten aus der Industrie evaluiert. Das neu gestaltete Konzept wird in einer weiteren Fallstudie mit demselben Automobilkonzern evaluiert.

Abstract

The business models of many organizations rely on information technology (IT) solutions and practitioners implement new applications to meet the corresponding business requirements. This results in large application portfolios (AP), more dependencies between applications, and AP complexity (APC). APC constitutes an important topic in enterprise architecture (EA) management and researchers as well practitioners have investigated complexity indicators and their relationships between each other over the last years. Transparency about the status of APC indicators is a crucial success factor in order to derive suitable actions for APC reduction. However, visualizations that provide this transparency are missing. In this context, the concept of Business Capability Maps (BCM) gains momentum. Enterprise architects use the BCM to analyze, plan and monitor business capabilities and define their long-term EA.

This thesis investigates, how to use BCMs to increase the transparency of APC. The core artifact of this thesis is a collection of 14 visualizations that facilitate APC transparency from different viewpoints considering specific APC indicators. In addition, three key performance indicators (KPI) for APC measurement and a software solution for the visualization will be developed and evaluated. The interrelationships between BCM and application information as well as the functionality of the visualization are presented in a concept. The evaluation of the artifacts shows that the visualizations increase transparency about APC and that concrete actions can be derived to reduce APC.

At the beginning of the dissertation, the term APC is defined and existing frameworks for AP Management (APM) are analyzed towards APC reduction based on a literature review. These insights are used to define a capability-based visualization concept that helps increase transparency about APC. The concept is implemented iteratively: the first iteration aims at measuring APC by defining three KPIs and visualize the results of these on a BCM. The KPIs and the visualizations are evaluated by conducting a case study within an automotive company. The results show that using the BCM as a visualization medium is useful, but the KPIs for APC measurement are inadequate. Based on this insight, 14 capability-based visualizations – which generate transparency about specific APC indicators – are defined within a second iteration. The visualizations are defined with two EA experts from two organizations and are evaluated by conducting interviews with 25 EA experts from the industry. The redefined approach is evaluated in a further case study with the same automotive company.

Acknowledgment

This thesis represents my contribution as a researcher at the Chair for Software Engineering for Business Information Systems (sebis) at the Technical University of Munich. The journey to this work is marked by valuable suggestions, discussions and feedback from several people. The dialogue with these people was essential for the success of this work and I would like to take this opportunity to thank them for their support.

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Most importantly, I would like to express my gratitude to my girlfriend Gina Katharina Lendl for her unconditional love, support, and patience during this challenging time. I am grateful for my family who have supported me during my whole life and always give me the feeling that all will work out okay.

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CHAPTER 1

Motivation

This chapter serves as an introduction to the following thesis. Section 1.1 outlines the problem domain and the resulting research questions (RQ) of this thesis, followed by a summarized overview of the contribution in Section 1.2. The conducted research approach is presented in Section 1.3 and the structure of the thesis and the following chapters are outlined in Section 1.4.

1.1. Problem statement and research questions

Considering the significant role of IT in today's society, organizations undergo fundamental changes in their EA [AG11, PP11, RB06]. With rising cost pressure and faster time-to-market lifecylces, IT managers face various issues during their EA transformation. A current study by the Society of Information Management – illustrated in figure 1.1 – gives an overview of the top ten most important IT management issues from 2006 to 2016.

IT Management Concerns/ Issues (a)	**2016**	**2015**	**2014**	**2013**	**2012**	**2011**	**2010**	**2009**	**2008**	**2007**	**2006**
Alignment of IT and/with the Business	**1 (41.7%)**	1	1	1	2	1	3	2	1	2	1
Security/Cybersecurity/Privacy (b)	**2 (36.0%)**	2	2	7	9	8	9	9	8	6	3
Innovation	**3 (23.2%)**	4	8								
Agility/Flexibility (IT) (c)	**4 (20.6%)**	7	13								
Agility/Flexibility (Business) (c)	**5 (19.9%)**	9	3	2	3	2	2	3	13	17	7
Cost Reduction/Controls (Business) (d)	**6 (19.7%)**	10	9	4							
Cost Reduction/Controls (IT) (d)	**7 (19.0%)**	8	17	5	5	10	8	5	7	4	5
Speed of IT Delivery/IT Time-to-Market (e)	**8 (18.2%)**	3	5								
Strategic Planning (Business)	**9 (15.6%)**	13									
Productivity/Efficiency (Business) (f)	**10 (14.5%)**	5	4	3	1	4	1	1	7	4	

(a) Blank cells, unless otherwise noted, indicate that the issue was not included that year.
(b) In previous years, "Security/Cybersecurity/Privacy" was referred to as "Security/Privacy."
(c) "Business Agility/Flexibility" and "IT Agility" were merged into an "Agility/Flexibility" category with Business and IT selections in 2015. "Agility/Flexibility (IT)" was measured as "Architecture Agility" in 2008.
(d) "Business Cost Reduction/Controls" and "IT Cost Reduction/Controls" were merged into a "Cost Reduction/Controls" category with Business and IT selections. Business cost controls were combined with "Business Productivity" in prior years.
(e) "Speed of IT Delivery/IT Time-to-Market" was combined with "Velocity" in 2013 and "Agility" through 2012.
(f) "Business Productivity" and "IT Efficiency" were merged into a "Productivity/Efficiency" category with separate Business and IT selections.

n=most senior IT leader in 801 unique organizations

Figure 1.1.: Top ten most important IT management issues 2006 – 2016 [So16]

The named issues in Figure 1.1 can rise from technical or organizational root causes. For instance, low agility/flexibility within IT can originate from missing capabilities or IT complexity [AG04, FN07]. One frequently discussed root cause for low agility and high costs is APC. Schneider and Matthes [SM14] outline that most of the mentioned issues in Figure 1.1 are consequences of APC, which arise from characteristics of APC drivers. Other scientists [SZ14, BA15] and practitioners [AB09, RS10] also identified APC as a significant issue in EA management (EAM) domain: in their research they outline high IT costs [ZG07, SM14], heterogeneous APs [SB11, SW13, Sc16], and decreasing agility [SM14] as consequences of APC.

In order to derive measures for addressing APC drivers and their effects, transparency about the status of APC is a prerequisite. Although a number of visualizations have been established in the last few years in the EAM community and tool vendors support any kind of visualization types [RZ14, AH16], visualizations that provide transparency about the characteristics of APC drivers and effects have so far only been investigated to a limited extent in research. However, in the last few years one visualization type – the BCM – gained high attention in the EAM community in order to acquire transparency about the EA and AP and derive measures for optimization [FM11, AS15].

The domain driven design paradigm by Evans [Ev03] already outlines the significance of aligning software solutions in their technical design, syntax and semantic to their respective domain (*bounded context*), which also holds true for EAs and APs. Since the BCM abstracts business-related abilities and not any technical-, business process- or organizational-related information in its structure. Thus, capability-based visualizations to increase transparency about APC drivers and effects – summarized as indicators – would be suitable.

Since a comprehensive study of our research group [AS15] reveals APC as an emerging issue in EAM and BCM as a promising tool for EAM, the following research hypothesis is defined:

> ***Research hypothesis:*** The BCM can be used to increase transparency about APC indicators.

It is necessary to investigate the definition of AP and APC and what kind of complexity indicators exist. These questions are investigated through literature research, presented in chapter 2. Based on these results, the concept of capability-based APC management and concrete visualizations for this concept can be defined. The concept is evaluated by two case studies with an industry partner.

The following RQs are defined:

> ***RQ 1:*** How is the conceptual design of capability-based APC management defined?

In order to use the BCM for APC transparency enhancement, it is important to define to which extent a BCM can be connected to an AP and by which mechanisms transparency can be increased. The concept of capability-based APC management relies on a layered architecture (data, logic, visualizations). All defined visualizations address APC from different viewpoints and use the BCM as a lens. Since the definition of the visualizations required two iterations (design, demonstrate, evaluate), the concept was slightly redesigned after the first iteration.

> ***RQ 2:*** What are suitable visualizations for capability-based APC management?

The visualizations are not intended to represent the general needs of IT management or EAM, but rather the characteristics of complexity indicators in the AP. For this purpose, visualizations have been defined that address concrete APC indicators. Two different approaches were tested: On the one hand, the approach of a KPI-based visualization and the visualization of concrete APC indicators on the BCM without calculations. On the other hand, this thesis provides visualizations that consider individual APC indicators to increase the transparency from certain viewpoints.

> ***RQ 3:*** How can a software solution support the enhancement of APC transparency using a BCM?

A software-supported solution that displays APC transparency in real-time is desirable to make the concept more practicable. Consequently, this RQ aims to investigate the design of a suitable software solution. The defined visualizations were evaluated by conducting two case studies with real data of an automotive company and are supported by a defined software solution that produces the visualizations automatically. The software solution is based on a requirements analysis with the automotive company.

1.2. Contributions

The main purpose of this thesis is to enrich APC management practices with visualizations that provide transparency about the status of APC indicators and support the definition of measures to reduce APC. This thesis contributes to research by producing four artifacts. Table 3.1 provides an overview of the contributions.

ID	Contribution	Description
C1	Concept for capability-based APC management	Since the evaluation relies on two case studies with an automotive company and considers a software solution to realize the visualizations, a conceptual design of capability-based APC management is defined in Section 3.1. The conceptual design explains which architectural layers should be considered for a software solution, which information is needed to produce the visualizations, what kind of colors should be used for the color coding, how the visualizations work (drill-down, etc.), and how the BCM can be interlinked with APC indicators. The initial concept is presented in Section 3.1. The redesigned concept is presented in Section 4.1.
C2	KPIs for capability-based APC management	The initial concept defines three KPIs to measure APC and visualizes the results of the KPIs on the BCM. All KPIs rely on APC indicators (from research and input from EA experts) and follows best practices for KPI definition. The KPIs and the development process of these is explained in Section 3.2. The KPIs were evaluated by conducting a case study with the automotive company and the results are illustrated in Section 3.3.3.
C3	Visualizations for capability-based APC	The core contribution of this thesis is a collection of 14 visualizations, each addressing APC from different viewpoints. Each visualization is explained in Section 4.3, comprising a description, an overview of addressed APC indicators and an information model. Every visualization was evaluated on its benefit and current use in practice by conducting expert interviews with 25 practitioners. The results of these interviews serve as a basis for the second case study (decision on visualization implementation). The results are presented in Section 4.4 (results of 25 interviews) and Section 4.5.3 (results of second case study).
C4	Software solution for capability-based APC	The developed software solution provides the possibility to produce the visualizations automatically, based on recorded functional and non-functional requirements of the case study partner. Although, the software solution is a prototype and mainly serves as a basis for the evaluation, it gives a first impression of what a fully developed solution can look like.

Table 1.1.: Overview of contributions

1.3. Research design

Today's IS methods, can be separated into quantitative and qualitative research methods. As argued by Myers [My97], *Qualitative research involves the use of qualitative data, such as interviews, documents, and participant observation data, to understand and explain social phenomena.* On the other hand, quantitative research describes *a research problem through a description of trends or a need for an explanation of the relationship among variables* [Cr02] and is characterized by analyzing numerical data with statistical methods. According to Edmondson and McManus [EM07], the choice of research method depends on the maturity of the theory and the type of data. If a theory has already been discussed in depth over time, it is worthwhile to investigate the research area with quantitative data [EM07]. In contrast to novel research areas, where the purpose is to investigate the *how* and *why* [Yi13] of behavioral events, in-depth analysis with qualitative methods is more suitable [EM07].

As outlined in Chapter 2, using BCMs for EAM, APM, or APC purposes is not studied in depth. As a consequence, the research design of this thesis follows qualitative research methods. As the thesis aims to achieve knowledge about a problem domain (APC) by designing and evaluating new artifacts (visualizations), the *Design Science Paradigm* by Hevner et al. [HM04] serves as a foundation for the research approach. Figure 1.2 illustrates the adapted IS research framework by Hevner et al. (adapted to this thesis).

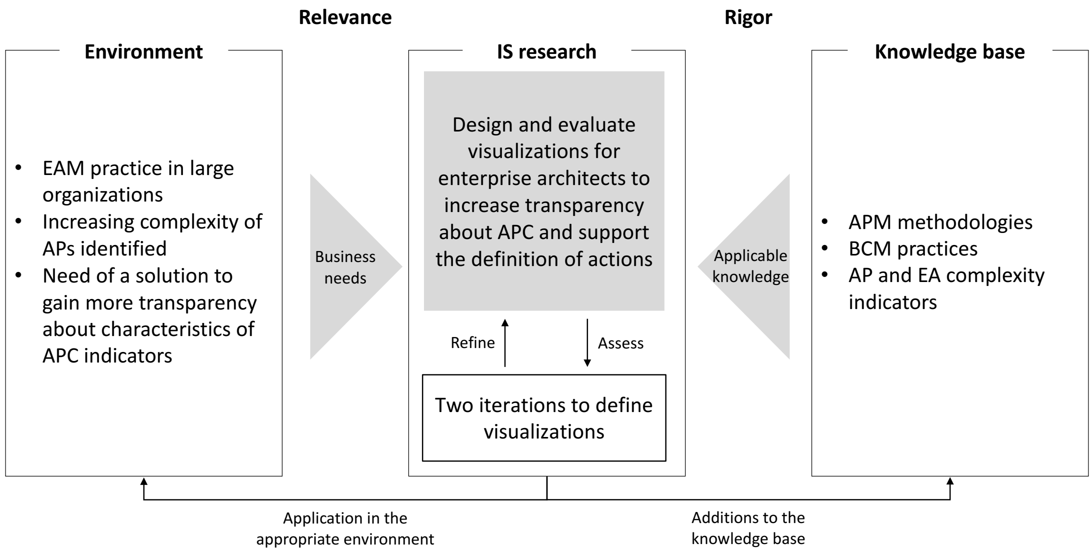

Figure 1.2.: Adapted IS research framework (based on Hevner et al. [HM04])

IS research is the core of the framework and is conducted in two complementary phases: the IT artifact is designed and developed (*Design/Build* phase) and then evaluated by case or field studies or other research methods (*Justify/Evaluate* phase) [HM04]. The results of these studies refine the developed artifact and the maturity of it increases iteratively. In this thesis, the core artifact is a collection of capability-based visualizations to increase transparency about APC.

The visualizations were defined and evaluated in two iterations. The first iteration is illustrated in Chapter 3, the second in Chapter 4.

The design and development of the artifact is influenced by the *Environment*, in which it is supposed to solve an identified problem. The environment composes the need of people, the used technologies, and organizational constraints (Organizational strategy, processes, culture, or structures). In this thesis, the environment is characterized by EAM practices in large organizations, the identified issues of increasing APC and the need for a solution to gain more transparency about characteristics of APC indicators. The identified requirements (*Business needs*) within the two case studies and the feedback by EA experts ensure the *Relevance* of the artifact and are documented in Chapter 3 for the first iteration and in Chapter 4 for the second.

State-of-the-art research and practices illustrate the *Knowledge base*. Foundations and related work on EAM, APM, APC, and BCM are considered and ensure the *Rigor* of the designed and developed artifact. Foundations and related work are documented in Chapter 2. In addition, Hevner et al. [HM04] define seven guidelines for effective design science research. The following paragraph outlines briefly what these guidelines are about and how they have been taken into account during this thesis.

Design as an Artifact: The produced artifact must be a concrete construct, model, method, or instantiation. This thesis provides a concept for capability-based APC management with 14 visualizations to provide transparency about the characteristics of APC indicators (*Model*). A software solution with four visualizations has been implemented and evaluated as a result of two case studies with real data of a practitioner (*instantiation*).

Problem Relevance: The artifact must address relevant business problems. The issue of APC is motivated in Section 1.1. Section 2.4 outlines the research gap based on the related work. The upcoming trend of BCMs in EAM is motivated in a recent publication of our research group [AH18].

Design Evaluation: As outlined by Hevner et al. [HM04] *the utility, quality, and efficiency of a design artifact must be rigorously demonstrated*. The conceptual design of the capability-based APC management and the defined visualizations were continuously defined and evaluated by conducting two case studies with real data.

Research Contributions: The produced artifact should enrich related work of the respective research field. Related work on APM has been enriched by a capability-based view considering already identified APC indicators in research and practice.

Research Rigor: The development and evaluation of the artifact relies on rigorous methods. The first iteration follows a KPI-based approach for the visualizations. The KPI definition relies on a literature review, following Webster and Watson [WW02] and best practices for KPI definition [AB17, JL03]. The evaluation was conducted with a case study and ten expert interviews. The results of this first iteration serve as an input for the second iteration. The 14 visualizations in the second iteration were designed in strong collaboration with two EA experts and were evaluated by conducting 25 expert interviews. The implemented software solution relies on recorded requirements by practitioners and were evaluated by conducting 13 expert interviews.

Design as a Search Process: The visualizations were developed continuously (two iterations) and are based on a literature review. Feedback by practitioners was considered during the complete research process. Figure 1.3 illustrates the research process and the conducted process steps.

Communication of Research: The research results should be presented to technology- and management-oriented audiences. The research results were published in several publications [AH16, AB16, AH18, AB17].

The research process aligns to the design science research methodology (DSRM) process model by Peffers et al. [PT07]. Figure 1.3 gives an overview of the conducted process steps, the deliverables of each step, and names the used methods.

Identify problem & motivate: The thesis starts to outline the problem domain and introduces the hypothesis and RQs. Our research group conducted an online survey with 31 EAM experts to identify current concerns in EAM practice [AH16]. The results of this study show that APC is an emergent issue and the BCM concept raises high attention in the EAM community. These findings and group discussions with researchers and practitioners serve as an input to shape the scope of this research.

Define objectives of solution: Based on a literature review, which follows the approach by Webster and Watson [WW02] the foundations and related work on this topic are illustrated. The related work gives an overview about introduced APM methods, identified APC indicators from research and practice, and use cases for BCM in EAM. Based on the findings, the research gap and the objectives of the proposed solution are concertized.

1. Iteration: The first iteration aims to define three KPIs that illustrate the complexity of an AP from three different viewpoints (architectural structure, quality, impact). The used variables for the KPIs base on identified APC indicators from the literature review and feedback from two EA experts of an automotive company.

Design & development: The KPI design follows the best practices for KPI aggregation by Jollands et al. [JL03]. The automotive company also agreed to act as a case study partner for evaluating the results of the KPIs with real data. The results of the KPIs should be visualized on the BCM of the automotive company. The visualizations should be produced by a software solution. The functionalities of the software solution were captured by documenting functional and non-functional requirements.

Demonstrate: The case study considers real data for one market of the company and considers data for 30 applications.

Evaluate: The defined KPIs, the software solution and the proposed visualizations were evaluated by conducting 10 expert interviews with employees of the automotive company. experts' feedback serves as input for the second iteration of the artifact production.

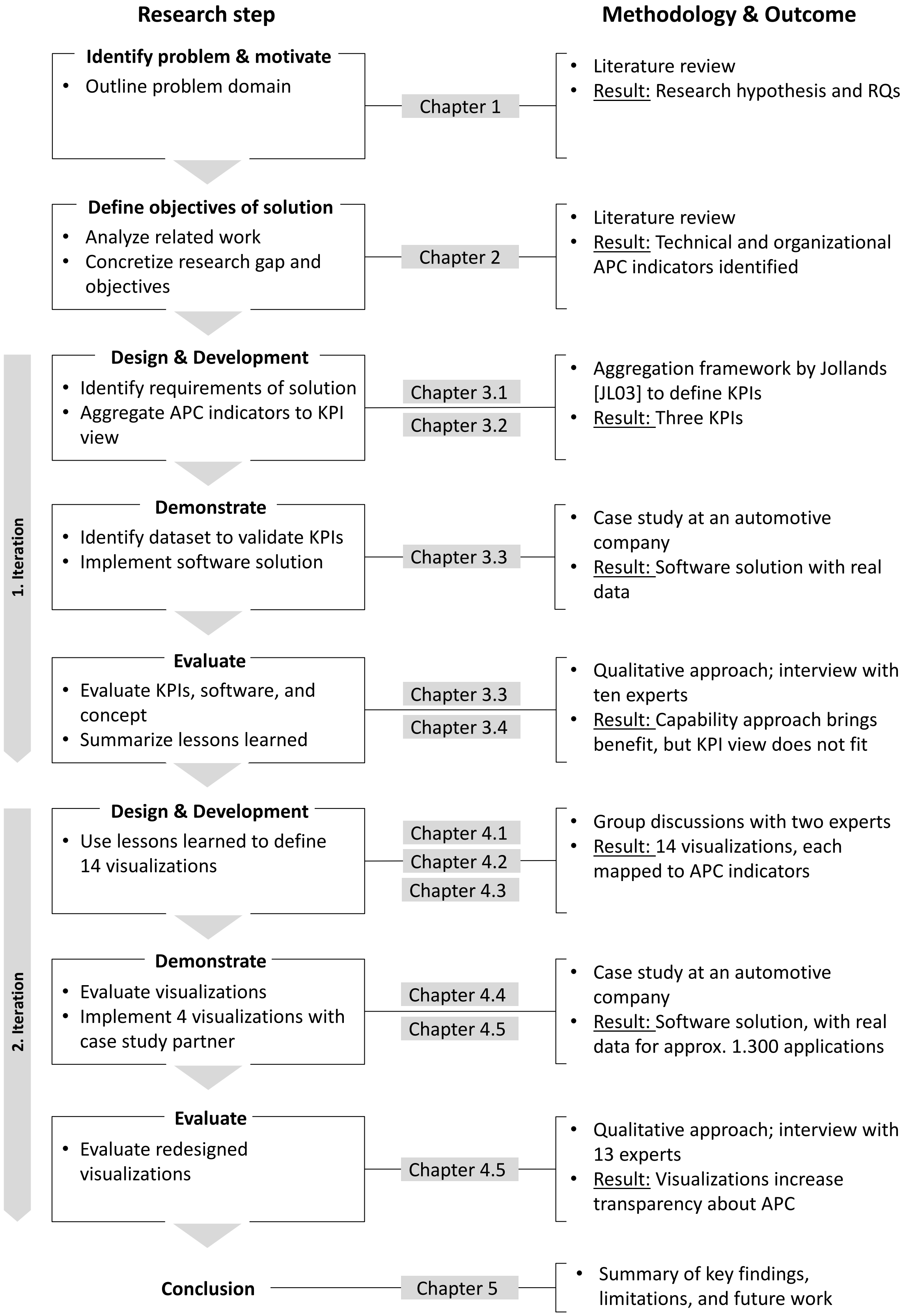

Figure 1.3.: Research approach and outline of the thesis aligning to Peffers et al. [PT07]

2. Iteration: The results of the first iteration reveal that the capability-based view on APC characteristics provides transparency about APC indicator characteristics. However, practitioners also explained, during the experts interviews, that a KPI-driven approach is not suitable. Visualizations that provide transparency about concrete APC indicators are more tangible and support the identification of concrete measures.

    Design & development: The concept of the capability-based APC management was redesigned. Together with an EA expert from an insurance company and one EA expert from the same automotive company that also participated during the first iteration, 14 concrete visualizations were designed. Each visualization provides transparency about characteristics of specific APC indicators.

    Demonstrate: The visualizations were evaluated on their benefit and feasibility by conducting expert interviews with practitioners from 25 different organizations. Based on the feedback, a case study with the same automotive company from the first iteration was conducted. The study comprised the implementation of four out of the 14 designed visualizations in the software solution from the first iteration (minor changes required). The decision on which visualizations should be implemented and evaluated in this case study, was made on the basis of the survey results (visualizations with high benefit) and the data availability of the automotive company.

    Evaluate: The implemented software solution and the comprised visualizations were evaluated by conducting 13 interviews with EA experts from the automotive company.

Conclusion: The thesis concludes with a short summary about the key findings, an evaluation of the defined research hypothesis and RQs and an outline of the limitations and the future work.

1.4. Outline of the thesis

Chapter 1 gives an overview of the problem domain and introduces the RQs and research hypothesis of this thesis. The contributions are outlined and the conducted research design and process are presented.

Chapter 2 presents the foundations and related work, based on the conducted literature review. The end of this chapter lay out, why the outlined work affects this thesis and concretizes, how the produced artifacts fit into the related research field.

Chapter 3 summarizes the conducted activities and results of the first iteration. It details how the KPIs were developed, designed, and evaluated. The Chapter ends with an outline of the lessons learned.

Chapter 4 summarizes the conducted activities and results of the second iteration. It explains the produced visualizations in detail, outlines how the design of them were evaluated with practitioners, and illustrates how a subset of the visualizations were evaluated in a real-life environment.

Chapter 5 discusses the defined RQs and research hypothesis based on the research results, outlines the limitations of this work and gives an overview of future work.

CHAPTER 2

Foundations

This Chapter provides the foundation and related work of this thesis. Sections 2.1 to 2.3 introduce the relevant research fields of this thesis (EA, EAM, APM, APC, BCM). Fundamental definitions are illustrated in these sections. Related work by researchers and practitioners is outlined in Section 2.4.

Based on the foundations and related work, Section 2.5 outlines the research gap and the position of this thesis in its corresponding research field.

2.1. EA and EAM

2.1.1. Introduction to EA

The first initiatives to formalize and outline the architecture of an IS in a structured way, was attempted by John Zachman [Za87] in the 1980s. Zachman outlines that success and costs of an organization's business depends on ISs and their structured management. A structured and standardized documentation of the implemented IS systems is mandatory for such a management initiative. Shifting the IS view to all relevant components in an enterprise ecosystem (e.g. databases, applications, business processes, and their respective interdependencies), illustrates, what an EA is all about. The present Zachman framework [Za14], provides the following definition of the term EA:

A structured set of descriptive representations relevant for describing an Enterprise and being employed such that an instance of the Enterprise can be created and such that the descriptive representations serve as a baseline for changing the instantiated Enterprise. [Za14]

Over the past years different definitions of EA evolved in science [RW06, WF06, BM08, DS09, BE12], practice [Ha09, Ke12] and established standards [Un10, IE11, Fe13]. Although these definitions look at an EA from different perspectives, the authors agree that an EA reflects an orderly representation of all entities and their interdependencies in an organization.

Considering EA as a model of software-intensive systems, the ISO/IEC/IEEE 42010 [IE11] defines the term architecture for software-intensive systems, whereby the standard deliberately ignores the words *Enterprise* or *Organization* as there are separate standards for this. Nevertheless, this work reduces many definitions to a common denominator. Consequently, the following definition of EA is crucial to this thesis:

Definition: Enterprise Architecture
Enterprise Architecture is the fundamental organization of a system embodied in its components, their relationships to each other, and to the environment, and the principles guiding its design and evolution.

[IE11]

Considering EA as a software-intensive system model, the ISO/IEC/IEEE 42010 provides a conceptual framework for architectural descriptions. Figure 2.1 illustrates the conceptual framework with the considered concepts and their relationships to each other.

An *Architectural Description* expresses the *Architecture* of a concrete *System-of-Interest* – or simply; system. The format of an architectural description is not defined in the standard and could be a set of models, documents, a repository, or other. A system is produced to cover interests of concrete *Stakeholders* in the organization. These interests are characterized by *Concerns* of the stakeholder – such as functions, usage, performance, security or other requirements.

An *Architecture Viewpoint* frames these concerns in terms of suitable visualizations. These are characterized by the choice of model, viewpoint languages, notations, methods and other modeling influence factors. An *Architectural View* expresses the architecture of the system from the view of a concrete set stakeholders and consists of one or more *Architectural Model*. A *Modelkind* sets conventions for an architectural model.

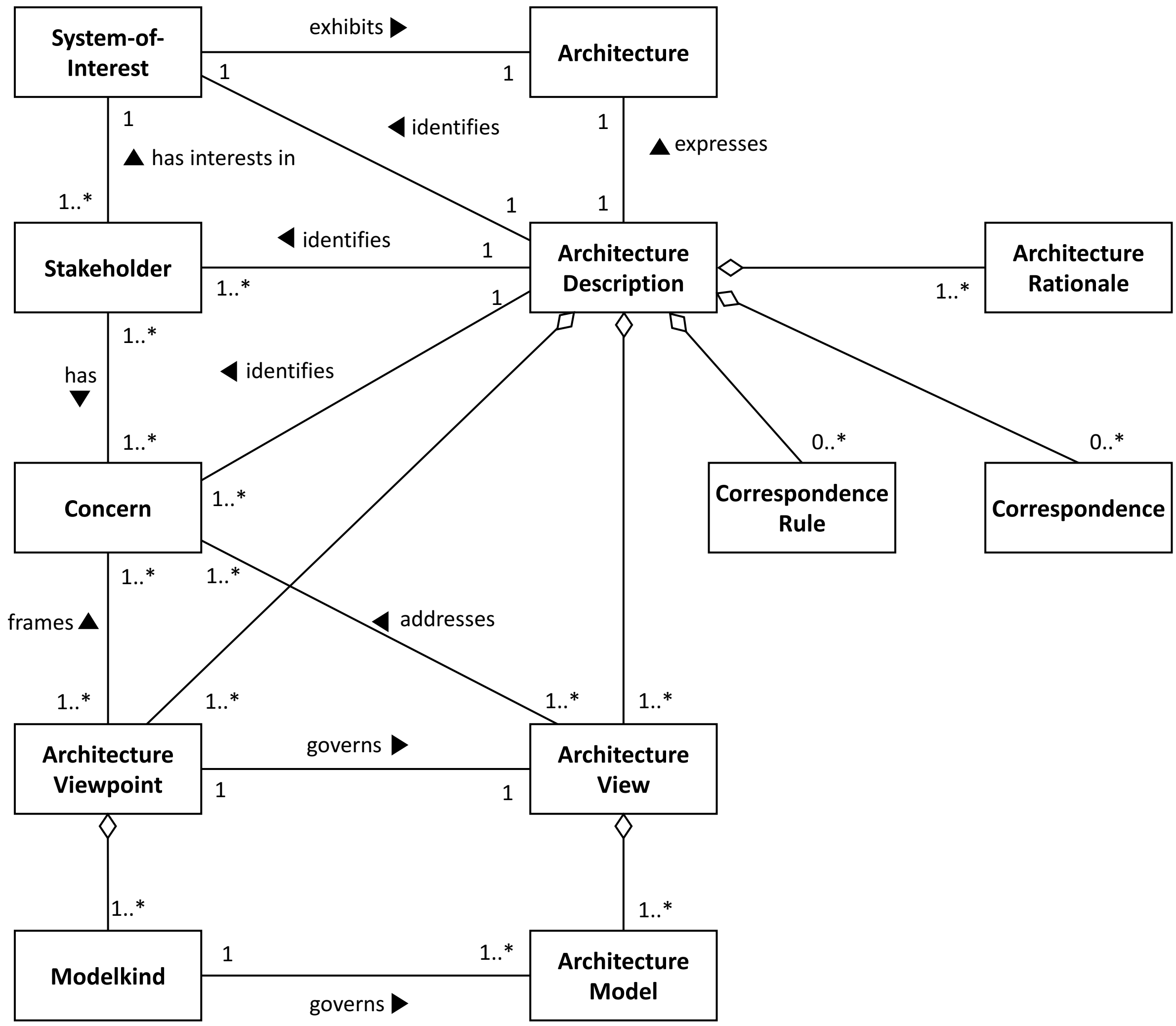

Figure 2.1.: Conceptual framework of the ISO/IEC/IEEE 42010 standard for architectural descriptions of software-intensive systems [IS11]

The architectural framework outlines the concepts and relationships of an EA, when considered as a software-intensive system. Other researchers provide different views on EAs with a more practical approach. These concepts are presented in the following section.

2.1.2. Layers of EA

As outlined in Section 2.1.1 an EA represents all components of an enterprise ecosystem and their relationships to each other. As summarized by Winter and Fischer [WF06], the number of artifacts could be substantial. Thus, several researchers suggest to use a layered representation of an EA [Sc03, WF06, TH04, Bu11]. It summarizes related artifacts to one layer. As each layer is documented in a separated model, the number of artifacts in each model – and consequently the relationships between artifacts and the complexity of each model – is reduced. Winter and Fischer [WF06] propose a hierarchical cross-layered view with five layers. Figure 2.2 illustrates their concept.

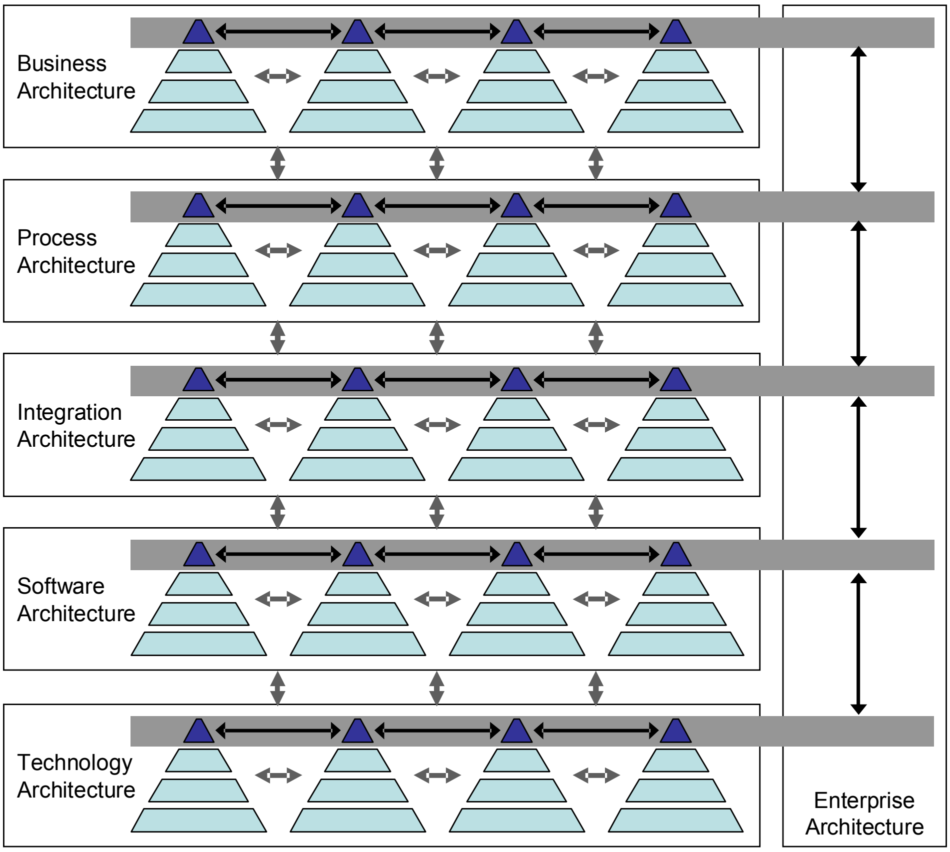

Figure 2.2.: EA as a cross-layer view of aggregated artifacts [WF06]

Winter and Fischer propose that most of the EA artifacts can be represented as aggregation hierarchies. For instance, microservices represent granular artifacts in software architecture and can be aggregated to an IT service. Each layer uses aggregation hierarchies *to represent artifacts on different levels of aggregation.* The EA layer is illustrated as a cross-functional layer, and *can be defined as the view that represents all aggregate artifacts and their relationships across all layers.* Further cross-functional layers – such as an information layer or security layer – are possible. Winter and Fischer propose the following layers in their cross-layered view.

- **Business Architecture:** This layer abstracts from any technical or operational viewpoint and represents the fundamental structures of an organization from a business strategy viewpoint [WF06]. The definition of the business architecture *is a prerequisite for architecture work in any other domain* [Th17a]. Artifacts could be *Organization/Actor, a Business Service/Function, a Contract/Measure Catalog*, or a *Product Lifecycle Diagram* [Th17a]. Winter and Fischer name *value networks, relationships to customer and supplier processes, targeted market segments, offered services, organizational goals, and strategic projects* as typical artifacts [WF06].
- **Process Architecture:** According to the *Architecture of integrated Information Systems* (ARIS) by Scheer and Nüttgens [SN00], a business process describes *a procedure relevant for adding value to an organization.* Although, ARIS defines the term "business process", the definition also holds true for processes in general. In other words, it describes a set of structured activities to achieve a service or task. The process architecture describes the organization of these services. It describes how services are developed, created, and distributed in the relevant enterprise context [WF06]. In line with Davenport [TH04], Winter and Fischer summarize *business processes, organizational units, responsibilities, performance indicators, and informational flows* [WF06] as typical artifacts.
- **Integration Architecture:** Enterprise integration ensures the controlled interaction between enterprise entities to achieve enterprise objectives [CD08]. These could be the integration between applications, infrastructure components, processes, or other entities. In this context, it ensures the integration of dataflows or interdependencies between applications or their components [WF06]. Possible artifacts are interface descriptions or *remote procedure calls, enterprise services, application cluster* and *integration systems* [WF06].
- **Software Architecture:** Applications make use of specific modules, interact with various business objects and make use of best practices and patterns. Although, the documentation of these artifacts is important, Winter and Fischer argue that the management, documentation and analysis is not the task of an EAM.
- **Technology Architecture:** The lowest layer represents the organization of hardware and network components. Artifacts are e.g. *hardware, communication, processing*, and other models.

A detailed table of artifacts for each layer is provided by Fischer and Winter in their publication [WF06]. As aforementioned, the EA layer is a cross layer which represents all aggregated artifacts on each layer and their interdependencies between each other. Although further layered concepts are presented by researchers [Sc03, TH04, WF06, Bu11], the core message of the layered architecture becomes clear: it is reasonable to arrange the fundamental structure of an organization's hierarchy in specialized architectures. Even if every layer organizes it's own architecture, model, best practices, responsibilities, and other artifacts, it is essential to document and evaluate interdependencies between layers – e.g. by aggregated artifacts – and to consider them in architectural decisions. Another concept by Buckl et al. [BM11] also organizes an EA in layers, but focuses on EA demands. They claim that *EA covers manifold different facets of the enterprise ranging from business-related aspects to more IT-related ones* and organize EA in different layers. The concept is illustrated in Figure 2.3.

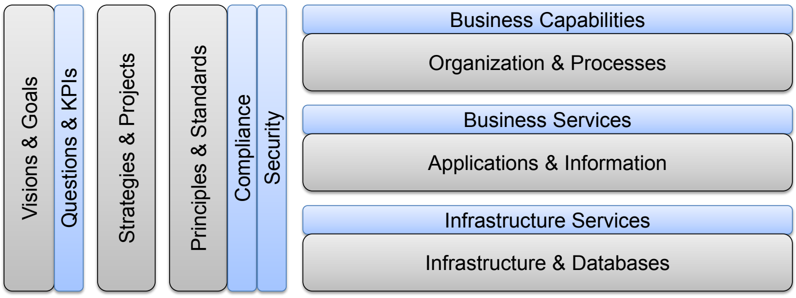

Figure 2.3.: Holistic view on an EA [BM11] (figure adopted by [BE12])

The above image consists of three cross functional and three hierarchical layers.

- **Infrastructure Services:** Routers, databases, hubs, switches, and other physical components represent the basis. Based on the infrastructure, several *Infrastructure Services* can be realized – such as internet access, Infrastructure as a Service (IaaS), or Platform as a Service (PaaS).
- **Applications & Information:** This layer organizes all applications and information that are necessary to provide *Business Services* to the organization. This support can be achieved in-house or outsourced to service providers.
- **Organization & Information:** This layer represents the structure of the organization. Artifacts are, for instance, business objects, markets, business processes, or functions. The artifacts are mapped to business capabilities and are organized in a BCM.

The hierarchical layers are similar to the proposed layer view by Winter and Fischer [WF06]: they follow a bottom-up approach and the organization of each layer depends on the artifacts and organization of the subsequent layer [WF06]. Although these models aggregate the five defined layers by Winter and Fischer [WF06] to three layers, three cross-functional layers are considered.

Vision & Goals: outlines the general direction the company would like to take and is documented in desirable objectives. *KPIs* and answers to *Questions* are suitable artifacts to measure and document the maturity. Based on this, organizations derive *Strategies* and plan *Projects* that drive the needed changes and are characterized by *Principles & Standards*, which are documented in *Compliance* and *Security* policies. The organization of the hierarchical EA layers and the information models have to meet the requirements and principles of the cross-functional layers.

It can be said that an EA reflects the ordered representation of enterprise-wide artifacts and their relationship to each other. The layered representation and organization of the information models and artifacts facilitate the documentation. The concepts by Fischer and Winter [WF06] and Buschle et al. [BE12] illustrate two possible approaches for layered EA organization. However, the organization of an EA is not a one-time event, but rather reflects a continuous management discipline. Depending on the involved stakeholders, the maturity of an EA, requirements of the market and other influence factors, information demands may change. EAM as an own management discipline is explained in Section 2.1.3.

2.1.3. Core principles of EAM

2.1.3.1. EAM as a continuous discipline

In order to keep an EA efficient, avoid mismatches, fulfill enterprise-wide principles, guidelines, and policies, a well founded management is necessary. Otherwise, EAs can become complex, growth heterogeneous, lead to lack of transparency, and become costly [AS12]. Moreover, an EA and its principles and guidelines has to be aligned continuously to the business model [AS12]. The continuous definition of EA guidelines, alignment of best practices and architectural policies, and the identification of structural mismatches in the EA is the mission of EAM.

Further researchers from science [WF06, Bu11, FA07] and from practice [Ha09, Ke12] have recognized and studied this management discipline over the last decades. For more information about relevant artifacts, methods, organizational forms, principles, guidelines, and other best practices, I refer to the cited literature. Based on Ahlemann et al. [AS12], EAM is defined as follows in this thesis.

Definition: Enterprise Architecture Management
Enterprise Architecture Management *is a management practice that establishes, maintains and uses a coherent set of guidelines, architecture principles and governance regimes that provide direction and practical help in the design and development of an enterprise's architecture to achieve its vision and strategy.*

[AS12]

In line with Ahlemann et al. [AS12], Buckl [Bu11], the *Architecture Development Method* in TOGAF by The Open Group [Th17a], and Niemann [Ni05], Roth et al. [RZ14] describe EAM as an iterative process. Figure 2.4 illustrates their concept.

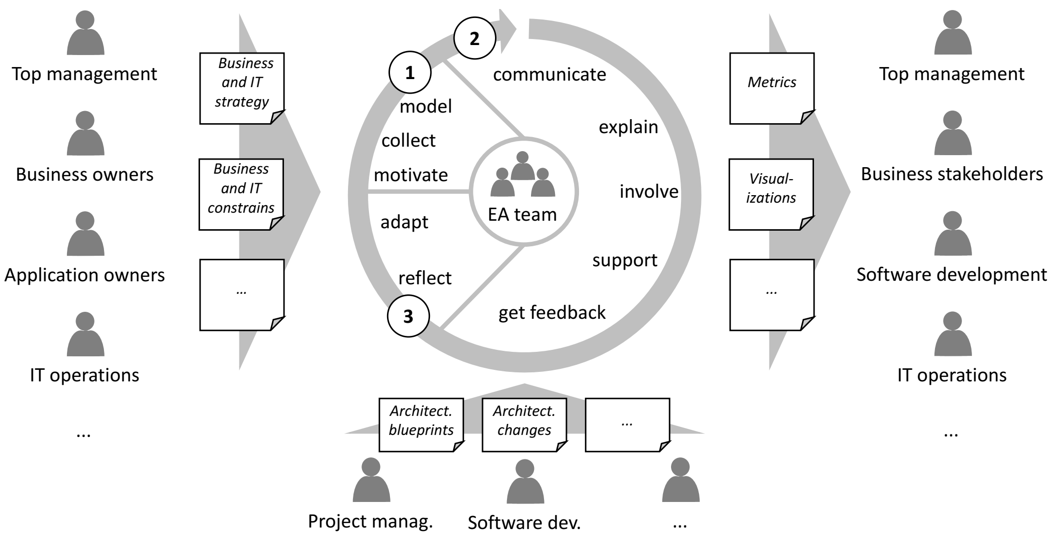

Figure 2.4.: EAM as an iterative management discipline [RZ14] (simplified)

- **Stakeholders and concerns:** As outlined by Haki et al. [HA16], Hacks et al. [HB17], and our research group [AH16], EAM addresses concerns of various stakeholders (business and IT). Concerns are, for instance, the present EA complexity, business-IT alignment, operational costs of the EA, and others. As outlined by Roth et al. [RZ14] the consideration of stakeholder's concerns is crucial for the success of an EAM initiative.
- **Activities by EA team:** Considering EAM as an established management discipline in the organization, the EAM team continuously collects necessary information to maintain the EA model. Incoming concerns from stakeholders will be analyzed, considering new *Architecture blueprints*, *Architecture-approval and requirements*, and necessary *Architecture changes*. The artifacts will be communicated by related stakeholders – such as *project managers* or *Software developers*, which affect the EA and the EA model due to project outcomes or software changes.
- **Presentation of results:** The EAM team addresses the concerns of the stakeholders by suitable *Metrics*, *Visualizations*, and *Reports*. An overview of EA visualizations is provided by Roth et al. [RZ14]. The EAM team reflect the feedback from stakeholders and subsequently adapt the EA model in the next phase.

EAM is in constant dialogue with business and IT stakeholders. The success application asks for a suitable placement of the management function in the organization. Key stakeholders, responsibilities, architectural standards, the role in business and IT projects, and other policies have to be defined, communicated and accepted among the organization. Concepts of how to place EAM in organizations are outlined in following section.

2.1.3.2. Positioning EAM in organizations

Although EAM is a group-wide task, the discipline still lacks acceptance in the organization. Stakeholders that work in a concrete domain within their organization with short-term goals and projects, do not see any benefit in EAM [Wi14].

Winter addresses this problem with a concept called *Architectural Thinking*, which describes the group-wide adoption of an EAM mindset in an organization [Wi14]. It claims that group-wide and long-term effects and goals should be considered in every IS decision. Comparing to traditional architecture management, architectural thinking recommends defining lightweight and pragmatic architecture methods and policies that can be adopted by almost all stakeholders. Responsibilities are distributed among all business departments to avoid EAM evolving to an ivory tower discipline. The enterprise architect should act as an enabler within the organization and support project teams with expert knowledge, negotiate dependencies between technical solutions, adopt and tailor the architectural framework to business needs, and define a high-level vision of the architectural vision within the organization [UK17].

Buckl et al. [BM09] define EAM as a *glue* on an enterprise-level management function. Their research introduces, how a central EAM function could be assigned in an organization and which information is exchanged with other management functions. Figure 2.5 illustrates their concept.

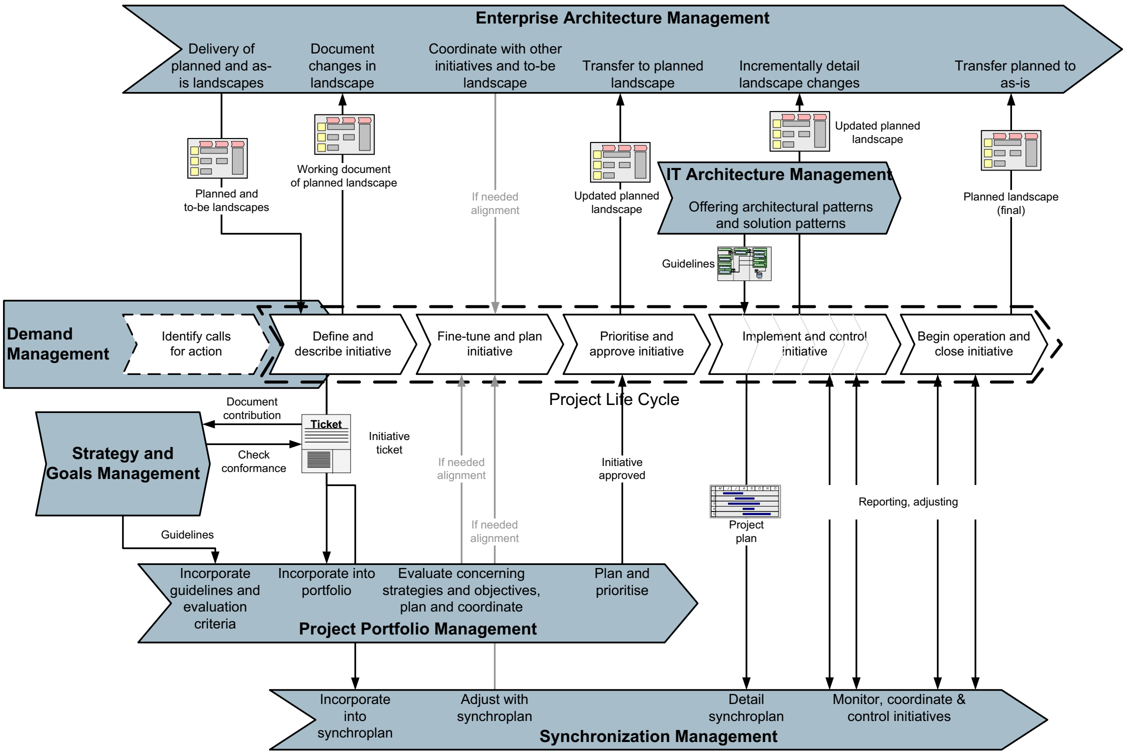

Figure 2.5.: The EA management function as ”glue” [BM09]

When starting a new initiative or project, EAM communicates the the *Planned and to-be landscape* to the *Demand Management*. Considering the architectural long-term plans, the *Demand Management* documents its initiative using an *Initiative Ticket*. The ticket will be communicated to the *Strategy and Goals-*, *Project Portfolio-*, and *Synchronization Management*. The aligned working document will be then communicated back to the EAM.

When coming to the prioritized and approved initiative, the Demand Management communicates the updated and fine-tuned initiative description to EAM. During the implementation, the *IT Architecture Management* supports the initiative with *Guidelines*. After the implementation, the IT Architecture Management communicates the *Updated planned landscape* to the EAM.

It is not about explaining every step of the concept, but to outline the role of EAM in daily initiatives in organizations. The concept shows that EAM has two tasks in every organizational initiative that affects the EA: it ensures that architectural changes within initiatives align with long-term EA goals by providing the planned and to-be architecture to the initiative leads. EA guidelines ensure the suitable implementation. Furthermore, EAM needs to be updated continuously with architectural changes and consider the results in the planned architecture, guidelines and other architectural artifacts. Figure 2.5 considers five stakeholders. EAM is the only stakeholder that is involved in every step. All decisions in an initiative can influence the EA. The continuous involvement and coordination with EAM is of great importance.

2.1.3.3. EAM frameworks

Over the last few decades, several EAM frameworks evolved – such as the Zachman framework [SZ92], DODAF [Un10], MODAF [Un12], ArchiMate [Th17], or TOAF [Th17a]. As outlined by Bente et al. [BB12] EAM frameworks are *a set of assumptions, concepts, values, and practices that constitutes a way of looking at enterprise reality via views on (architectural) models.* and *offer a fundamental structure, serving as a scaffold for developing, maintaining, and using EA.* In the following two well-known frameworks – the Zachman framework [Za87, SZ92] and the TOGAF framework by The Open Group [Th17a] – will be briefly described.

In 1987, John Zachman outlined the importance of defining, documenting, and presenting architectures of ISs [Za87]. Based on this cornerstone, the Zachman framework evolved, which provides a structured way of defining and presenting EAs. The core of the framework is a two-dimensional matrix, which illustrates what kind of aspects should be considered from which perspective to successfully setup an EA. Figure 2.6 illustrates a simplified view of the matrix.

	What	How	Where	Who	When	Why
Context	Inventory identification	Process identification	Distribution identification	Responsibility identification	Timing identification	Motivation identification
Concept	Inventory definition	Process definition	Distribution definition	Responsibility definition	Timing definition	Motivation definition
Logic	Inventory representation	Process representation	Distribution representation	Responsibility representation	Timing representation	Motivation representation
Physics	Inventory specification	Process specification	Distribution specification	Responsibility specification	Timing specification	Motivation specification
Components	Inventory configuration	Process configuration	Distribution configuration	Responsibility configuration	Timing configuration	Motivation configuration

Figure 2.6.: The Zachman Framework for EA – The Enterprise Ontology [Za11] (simplified)

The Zachman International, Inc. outlines that the framework *is a metamodel and unlike a method* [Za11], each row is a view of the architecture from a certain perspective. The columns illustrate communication interrogatives. The cells illustrate what kind of documentation or definition is necessary for a certain view. Example: An *Inventory definition* outlines essential business entities and their relationships to each other and could be documented with an entity relationship diagram.

The framework is a suitable introduction to EAM and helps to understand the fundamental cornerstones of an EA and its models. However, the framework does not include methods, visualizations, or any other assistance to define, develop, or maintain EAs [Ha13].

The TOGAF framework by The Open Group [Th17a] is one of the most adapted frameworks in the EAM community [Ha13]. The first version was introduced in 1995, which was continuously improved over the last few years. The current version is TOGAF 9.1 [Th17a]. The framework documentation consists of six parts:

- ***PART I – Introduction:*** The introduction provides basic concepts of EA and TOGAF. It outlines what an EA is, the benefits of EAM, definitions and abbreviations, and the core concepts of TOGAF.
- ***PART II – Architecture Development Method* (ADM):** The ADM ist the heart of TOGAF. It *describes a method for developing and managing the lifecycle of an enterprise architecture* [Th17a]. It consists of a preliminary phase as a starting point, following seven consecutive phases to develop an EA. All seven phases are continuously driven by a requirements engineering process which illustrates the center of the cycle.
- ***PART III – ADM Guidelines and Techniques:*** The ADM can be adapted to deal with various scenarios and organization specific best practices. Part III enriches ADM with guidelines, architecture development techniques, architecture patterns, gap analysis techniques, suggestions for migration planning, and other best practices and topics that should be considered when designing an EA.
- ***PART IV – Architecture Content Framework:*** During the EA definition phase, enterprise architects *produce a number of outputs as a result of their efforts, such as process flows, architectural requirements, project plans, project compliance assessments, etc.* [Th17a]. The Architecture Content framework provides guidance on how to organize and document the deliverables.
- ***PART V – Enterprise Continuum & Tools:*** When defining an EA, TOGAF suggests to design partitioned architectures, rather then one single unified architecture which meet requirements of specific stakeholders [Th17a]. PART V provides best practices on how to pursue the partitioning, how to design an architecture repository, and guidance to select a toolset for maintenance purposes.
- ***PART VI – TOGAF Reference Models:*** Part VI provides a technical reference model with best practices for taxonomy definitions, and visualizations. It also provides a concept of an integrated information infrastructure reference model with a taxonomy.
- ***PART VII – Architecture Capability Framework:*** The last part provides best practices for a EA governance. It outlines how to assign an architecture capability, what architectural boards should be introduced, an architectural maturity framework, and other EA governance best practices.

Hanschke summarizes that TOGAF is a comprehensive and generic EA framework that addresses the complete lifecycle of an EA and provides a wide-ranging set of reference and component descriptions [Ha13]. Other researchers criticize the missing *step-by-step use* of the frameworks [BB12] or that it *does not provide as much detail from the planning and maintenance aspects.* [UM06]. TOGAF also addresses BCMs for EAM, which is crucial for this thesis. Further details are explained in Section 2.3.

2.1.3.4. Pattern-based EAM

Section 2.1.3.1 and 2.1.3.2 outlines the core mission of EAM and how it interacts with other management disciplines. Frameworks like TOGAF [Th17a], the Zachman framework [Za87, SZ92] or FEAF [Fe13] provide a collection of best practices to design, plan, implement, and maintain EAs. However, practitioners claim that *no formal steps exist for defining, maintaining, and implementing EA and EA frameworks are not rigid enough in describing these steps* [LK10]. Although EAM concerns recur in various organizations, they often share the same pattern throughout any industry sector. Originated from the software engineering, a design pattern is a recurring solution for common problems and advise users with concrete activities that can be taken to sovle the problem [Ga94]. Based on this idea, Ernst introduced the pattern-based EAM approach [Er08]. An EAM pattern is a *general, reusable solution to a common problem* [Er09]. The original approach from 2008 consists of four concepts (*Concern*, *Methodologies*, *Viewpoints* and *Information model patterns*) and were extended with *Influence factors*, *Stakeholders*, *Architectural principles*, and *Data collection patterns*. A pattern follows the rule of three [Co96], which means that a *documented pattern must provide reference to at least three known uses in practice to ensure the re-usability of the provided solution* [BM13]. Figure 2.7 illustrates the extended EAM pattern approach by Schneider and Matthes [SM14].

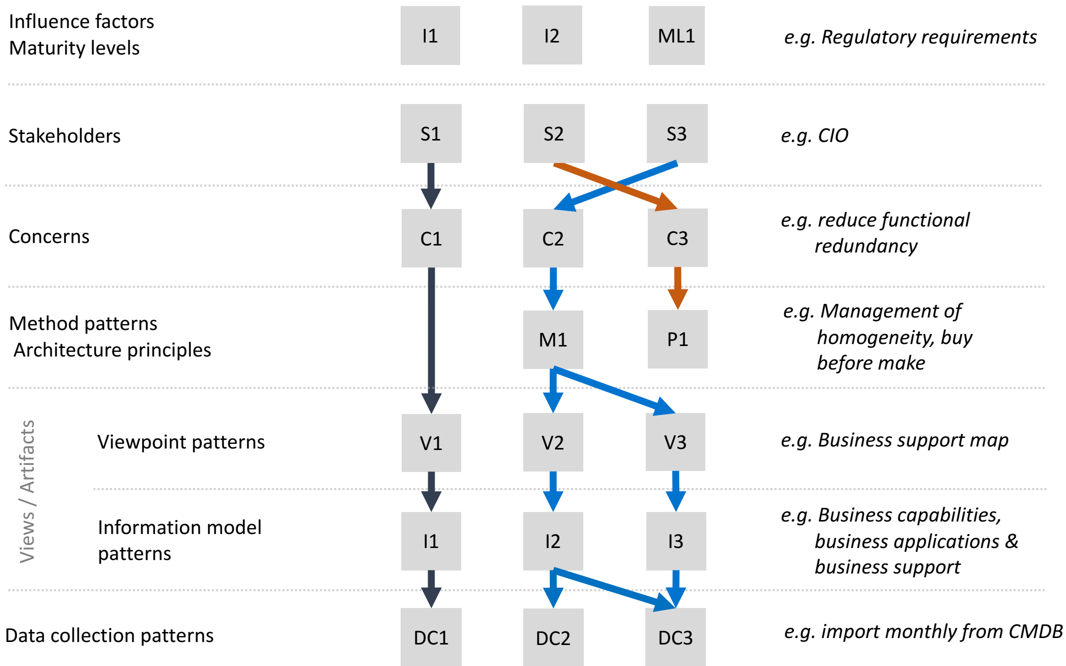

Figure 2.7.: Overview of the extended EAM pattern approach [SM14] (simplified)

- **Influence factors/Maturity levels:** EAM has to be *organization-specific* and *compatible with [...] embedding conditions* of the organization [Bu11]. Influence factors from the market – such as regulatory requirements or trends in the market – and inside the organization – such as cultural aspects – affect the strategy and the projects of the organization and consequently how EAM is proceeded.

- **Stakeholders:** As outlined in Section 2.1.3.1, EAM addresses concerns and information needs of stakeholders. A pattern addresses the concern of one or several stakeholders. An excerpt of identified stakeholders and their concerns is illustrated in Table 2.1. A full list is documented in the Enterprise Architecture Management Pattern Catalog V2 [AS15].
- **Concerns:** A concern is a management objective or an information need [BE08]. Table 2.1 illustrates an excerpt of the identified EAM concerns within the Enterprise Architecture Management Pattern Catalog V2 [AS15].
- **Methodology patterns/Architecture principles:** Schneider and Matthes [SM14] define methodologies as *steps to be taken to address a given concern.*. Architecture principles are holistic EA design principles [GP11].
- **Viewpoint patterns:** *A viewpoint is a medium that illustrates the current status of a concern, usually presented by a visualization* [AH16].
- **Information model patterns:** An information model describes the required information to produce the visualization.
- **Data collection patterns:** Required information is typically extracted from the EA repository and various other sources. A data collection pattern describes documentation standards – such as refresh frequency or responsibilities – of dates.

The contribution provides an example for the illustrated pattern in Figure 2.7 (blue arrows): stakeholder 3*(S3)* is interested in concern 2 *(C2)*. C2 can be addressed with the methodology 1 *(M1)*. The status of M1 can be visualized with viewpoint 2 or 3 *(V2, V3)*. The required information for the viewpoints are documented in information model 2 and 3 *(I2, I3)*. The required data of these information models are maintained with common practices of data collection pattern 2 and 3 *(DC2, DC3)*.

As summarized by Haki [HA16], Stakeholder groups are very fragmented in the IS community and interests are distributed heterogeneously. ISs are designed to meet *business needs, priorities, and objectives* by different stakeholders [Ki04] and ask for strong collaboration among business departments, software engineers, enterprise architects, project managers, and others [Po99, Le05, SC11]. The same pattern can be transferred to concerns in EAM. Although, two different stakeholders may be interested to solve the same concern, the viewpoints and thus the visualizations may differ (e.g. APC by visualizing the average (avg. number of application interfaces or the avg. age of an application within a business capability).

In 2015, our research group investigated which EAM stakeholders exist in organizations and what concerns they have. Table 2.1 shows that EAM is not solely an IT matter, but also involves business stakeholders across all organizational hierarchies. The number in each cell shows how many organizations (out of 31) explained that the respective stakeholder (column) is interested in the concern (row). For instance, three organizations explained that the enterprise architect is interested to solve the concern *breached architectural blueprints*). The same concern is addressed by 11 other stakeholders. The first row (*Addressed concerns (out of top 27)* summarizes in how many of the listed concerns the stakeholder is interested in. The last column shows if the concern was already addressed in the Enterprise Architecture Management Catalog 2008 [BE08].

For this thesis, it is important to outline which stakeholder group is interested in APC. In contrast to 2008, the results show that the APC is on the EAM agenda (see ID 08 in Table 2.1) and enterprise architects have the highest interest to investigate this concern. The artifacts that should be produced have to fulfill functional and non-functional requirements of a stakeholder group. Based on the findings by our research group, the design phase will largely consider requirements of enterprise architects. The identified requirements of the first iteration are illustrated in Section 3.3.2.2 and of the second iteration in Section 4.5.2.1. Consequently, enterprise architects have a significant role during the evaluation of the artifacts.

ID	Concerns	Enterprise architect	Domain / solution architect	Chief information officer	Technical architect	Head of department IT	Head of department business	Project manager IT	Chief financial officer	Business / process architect	Application owner	Chief operational officer	Business owner	Portfolio manager (Business / IT)	Controller (Business / IT)	Project manager business	Corporate development / governance	IT security & compliance	**Addressed in EAMPC 2008**
	Addressed concerns (out of top 27)	27	26	25	23	24	23	18	14	14	12	18	11	9	6	6	4	4	
01	Breached architectural blueprints	3	1	2	3	3	20	22	19		1	1	1			1			x
02	Definition of target application architecture	13	11	9	3	10	4	1				4	3			1	1		
03	Check to replace / keep used technologies	4	1	24	27	2													x
04	Map applications to business capabilities	13	7	5	1	4	4	1	3	6	2	2	3	1					
05	Alignment application architecture and business	10	6	6	1	5	5	2	2	4		3	3	1					
06	Detection of consolidation potentials	13	5	1	3	6	2		1			1		1	1	1			x
07	Define long-term application architecture	12	6	8	2	7	4					2	1				1		x
08	Reduce application architecture complexity	13	3	9	4	7	2		1					1	1				
09	Merge two different application architectures	11	10	5	3	3	2	3	1			1							
10	Supported applications by business processes	10	6	5		1	2	2		7		3	1						x
11	Shut-down impact of infrastructure component	6	5	3	14	3	2				3	1							x
12	Used infrastructure for applications	7	3	5	12	2	2				3	1							x
13	Define projects to increase standardization	6	5	5	6	4	2	1	1	1	2	1							x
14	Get transparency about IT costs	4		11		6	2		5				3			2		1	
15	Architectural assessment of change requests	6	8	3	4		1	4	1	1	2					2			x
16	Assign available IT budget to projects	8	1	7		3	2	1	3	1		1		3	2				x
17	Reduce operations and maintenance costs	4	3	7	1	7			4		2	2	1		2				x
18	Determine interfaces of applications	8	8	1	2	1		3		2	4						1	1	x
19	Data flows (business objects and applications	10	5	1	2		1	2	1	3	1		1					1	x
20	Align activities to modify application architecture	6	5	4		4	2	2	1	1		3	1	2					x
21	Identify dependencies between applications / projects	10	6	1	2	2		4			2			1		1			x
22	Identify dependencies between objects and interfaces	9	5		1		2	1		2	3		2		1			1	x
23	Communicate added value of EAM	10	4	2	3	4	2	1				1							x
24	Used applications by organizational units	10	6	2	1	1	1	3		1	2							1	x
25	Affected applications by projects	8	4		2	1	1	4		1				4					x
26	Outline projects to replace individual software	5	5	1	3	3	1		1	1		1	1			1			x
27	Remove monolithic applications	6	2	4	1	3	3	1		1		1							

Table 2.1.: Top 17 EAM stakeholders and their needs in 2015 [AH16]

2.1.4. APM as a sub-discipline of EAM

As outlined, in Figure 2.2, a layered EA view contains a software architecture layer which represents all software artifacts in the EA [WF06]. In terms of EA, an application is a software *designed to perform specific tasks, such as word processing, database management, or graphics* [Th17a]. Schwinn and Winter [SW05] explain that applications can be defined from a technical or business view.

- **Technical view:** An application is an aggregation of certain software artifacts (e.g. modules, components, data structures) that are closely related (e.g. call, access).
- **Business view:** An application represents an aggregated summary of specific functionalities that are closely related to each other through collectively supported business processes, shared information, shared reutilization and/or shared responsibilities.

Further definitions are provided by Riempp and Gieffers-Ankel [RG07], who define *applications as a specific class of IS that supports business processes directly* or Maizlish and Handler [MH05], who outline that an application is *an aggregation of software code impounding business logic and rules, transforming users or systems input into data output, for the purpose of automating and optimizing business functions, processes, tasks and activities therein.* The definitions show that applications can be defined either technically or business-oriented. Within this thesis, an application is defined as follows:

> **Definition: Application**
> An application is a software solution designed to perform a sum of coordinated functions, tasks, and activities to provide benefit for business entities or users.

Differentiation of software and application: since the term *application* plays a significant role in this thesis, it is important to clarify the difference between application and software. As summarized by Freund [Fr07], software illustrates any type of program code to control actions of hardware. An application is a certain type of software: as already outlined, an application illustrates a software solution which is designed for a user oriented task and provides benefits for the user, or in the enterprise context, to support a business process. This thesis considers only applications. Any other type of software is not in scope of this thesis.

In the 1980s Gibson and Nolan [GN74] came up with the idea to manage the lifecycle of applications in a portfolio. They differentiate between four stages of an application (*Initiation, Expansion, Formalization, Maturity*) and argue that an application becomes more important over time and a structured view and management of the AP is a crucial task. In this thesis, the definition of AP aligns to the definition by Riempp and Gieffers-Ankel [RG07].

> **Definition: Application Portfolio**
> An application portfolio is the sum of all implemented applications in a bounded application architecture of an organization.

In the context of EA, application architecture illustrates the components of an AP including relationships between the entities.

Originally from the finance domain, portfolio management aims to optimize the portfolio regarding *relevant and irrelevant* entities and increase the return-on-invest of it [Ma68]. Derived from the definition of EAM which *establishes, maintains and uses a coherent set of guidelines, architecture principles and governance regimes* [AS12] for EAs, APM does the same for APs. As summarized by Yilmaz [Yi17], APM can pursue two different approaches.

- **Financed-based view:** Management of the AP based on financial metrics like return-on-invest or the business value of applications [Sw06, BA11].
- **EAM view:** Management of the AP based on *business process and capability support, business objectives and missions,* and *underlying technologies* [Yi17]

McKeen and Smith outline [MS10] that APM optimizes the portfolio by removing assets that are no longer used or do not perform well and if necessary, replace them with new assets. In this context, assets are applications. The thesis follows the APM definition of Simon et al. [SF10].

> **Definition: Application Portfolio Management**
> *Application Portfolio Management is the ongoing application of systematic and structured decision-making processes to evaluate an organization's applications along various dimensions (from a business and a technical viewpoint), weigh various actions for the purpose of optimization, and implement appropriate actions to resolve identified issues and meet key enterprise objectives. The promise of Application Portfolio Management lies primarily in reducing the complexity of the application landscape, which is approached from a holistic viewpoint.*
>
> [SF10]

An AP illustrates one of several layers of an EA. APM is a sub-discipline of EAM. Even though EAM policies also hold true for APM – such as transforming monolithic IT solutions to microservices or increasing the speed of development cycles in the EA – the fulfillment of certain tasks is carried out by APM. For instance: EAM pursues the goal to streamline the EA by focusing on certain technologies and reduce redundancy in the AP. What exactly needs to be done in the AP and how to achieve this goal is the responsibility of APM.

2.2. Application portfolio complexity

Even though complexity is defined as fragmented in different research fields [VM07, AG15], researchers agree that complex systems are characterized by a large number of self-organized components with no central control [Ba96] which interact with each other in a large network [Mi09, AG15]. Schneider defines a system as *a set of elements and their interrelations which are delimited by their environment* [Sc16]. Although research on complex systems theory [Ba02] and eneral systems theory [Vo03] is a broad research field, further details are not of importance for this thesis. Now considering an AP as a system, the number of applications (components) and their interfaces and dataflows between each other (interactions) can be seen as an equivalent definition of the term.

However, a closer look into literature reveals that there is a multi-faceted definition of the term [Mo09a, RS10, DW11, SW13, LB14, SZ14, BA15, SR15]. Schneider and Matthes [SM14] and Mocker [Mo09a] for instance, agree that APC is the result of certain complexity drivers and their effects. Complexity drivers could be of a technical (avg. number of interfaces, age of an application, etc.) or organizational (interlock between business departments, change management plan, etc.) [Mo09a, SM14, AB16a] nature. Effects might be: increased IT operational costs, decreased agility, or a high amount of incident tickets [Mo09a, SM14, AB16]. In this case, complexity drivers base on characteristics of single applications. The aggregated view on the characteristics of all applications determines the effects of APC. A portfolio view – defining and calculating the heterogeneity of APs – is another view on this phenomenon and is introduced by Schuetz et al. [SW13]. However, the heterogeneity could also be interpreted as an effect of APC. In this thesis we aggregate APC drivers and effects as APC indicators. The thesis employs the following definition of APC.

Definition: Application portfolio complexity
Application portfolio complexity is the manifestation of application portfolio complexity drivers and their effect on the application portfolio.

The outlined contributions are explained in detail in Section 2.4.2. Since the considered APC indicators rely on the results of the literature review, a list and explanation of them is illustrated in Table 2.5.

2.3. Business capabilities

2.3.1. Idea and nature

The *resource-based view* suggests to *look at firms in terms of their resources rather in terms of their products* to achieve a competitive advantage [We84]. A resource-based view *would throw a different light on strategic options* [We84] and thus advise next steps to take on a certain market. Resources are *all assets, capabilities, organizational processes, firm attributes, information, knowledge, etc.* [Ba91] of the organization.

The term *capability* is defined as fragmented in research [Gr96, BK00, US04, KL10, Th17a], whereas most of the definitions argue that a capability is an ability or knowledge, which supports the process of a certain task to achieve a goal. Consequently, a business capability is an ability that supports the achievement of business goals. Business capabilities can also be seen as synonymous of *core competencies* which illustrate *the collective learning in the organization, especially how to coordinate diverse production skills and integrate multiple streams of technologies* [PH90]. Business capabilities define *what* to do, rather than *how* [SC12, Re13, Ha13]. Research provides several characteristics of business capabilities: they encapsulate from any resources, processes or IT components, are stable over time, do not overlap in terms of their content, can be broken down to sub-capabilities, and share the same structure [BM05, Ke09, SC12, Fr14]. A BCM is a structured view of all business capabilities in an organization. Figure 2.8 illustrates an example of a BCM and business capabilities.

The thesis adheres to the following definitions:

Definition: Business Capability
A business capability describes a skill or ability that an organization uses to perform its core function. A business capability encompasses and describes all applications, roles, and skills used to provide a business function.

[AH18]

Definition: Business Capability Map
The Business Capability Map is an ordered representation of all business capabilities within the organization.

[AH18]

Consider a BCM of an original equipment manufacturer (OEM). The BCM consists of ten business capabilities (*Customer Service, Order & Logistics, Marketing, Production, etc.*). The BCM considers multiple levels of abstraction [SC10]. Each business capability on the highest level (level 0 (L0)) consists of multiple sub-capabilities (level 1 (L1)). For instance, *Customer Service* consists of *Warranty, Repairs* and *Complaint* and the L0 business capability *Finance* consists of *Accounting, Controlling, Compliance, Taxes* and the *Consolidation* business capability. The level of abstraction can be enlarged (L3, L4, etc.). The BCM illustrates all capabilities the OEM needs to fulfill its business goals.

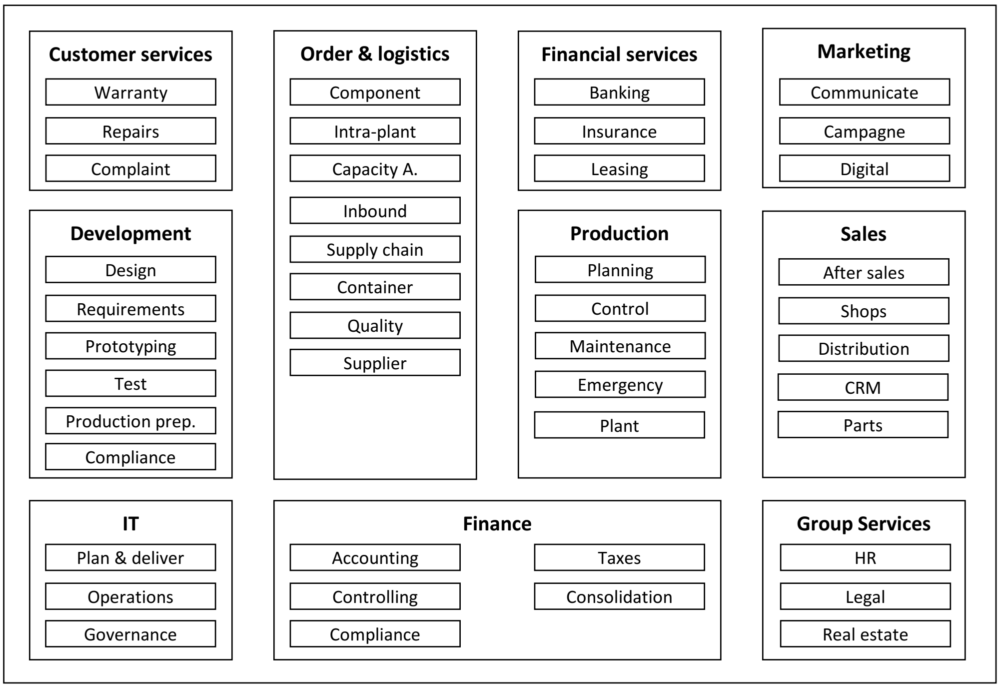

Figure 2.8.: Example of a BCM

As mentioned in the definition, a business capability does not only consist of a description, but should also explain what applications are needed to keep the business capability running, allocation of roles, and needed skills. TOGAF suggests documenting a business capability by adding information about three *Dimensions* (*People*, *Process Material*). Further views are provided by Klinkmüller et al. [KL10], Leonard [Le95], and others [MB06, Fr14]. However, an EAM related documentation is of greater importance for this thesis. The allocation of applications to business capabilities is crucial for EAM purposes. Table 2.2 illustrates an example of a business capability fact sheet. The example is based on the documentation standards of the case study partner of this thesis and does not claim to be complete. Adjustments of the fact sheet, for instance adding supported business processes, are possible.

In the example, five attributes define a business capability. The *Name* shows which business capability is involved. The *Business capability owner* is the person in charge of the respective business capability. The named staff member is the main owner of the business capability, acts as a single-point-of-contact in the organization, and has to ensure that the business capability works properly. The *Description* documents the provided abilities and the *Owned business objects* attribute which data in the EA repository (or other business object source) is is maintained. The *Supported application systems* outlines which applications support this business capability.

Attribute	Description
Name	Operations
Business capability owner	Mr. Max Mustermann (IT operations department)
Description	• Operate all implemented IT- and technical services, • Decommission IT- and technical services in time • Fulfill user requests, resolve service failures, fix problems
Owned business objects	• Incident • Problem • Event • Change • SLA
Supported application systems	• KPI reporting tool • Application performance monitoring tool • IT service management tool

Table 2.2.: Example of a business capability documentation

2.3.2. Classification of business capabilities

Figure 2.8 represents all business capabilities equally. The description of the business capabilities provides further information about their purpose in the organization. However, the distinction between business capability types helps to derive strategic priorities. Referring to the proposed BCM of an OEM in Figure 2.8: the *Development* capabilities might have a higher priority then the business capabilities *HR* or *Taxes*. The *Development* business capabilities are crucial for the business and are what may lead to a competitive advantage, rather than *HR* or *Taxes*. Leonard suggests the following distinction [Le95]:

- **Core capabilities:** provide a competitive advantage for an organization. They cannot be easily imitated by other organizations and have been built up over time [PH90, Le95, Gr96].
- **Supplemental capabilities:** provide a competitive advantage for an organization but can be easily imitated by others [Le95, BM08a].
- **Enabling capabilities:** are crucial to keep the business running but does not have any self purpose [Le95, BM08a].

Further classifications are dynamic capabilities [TP98], distinctive capabilities [Ka95], and organizational capabilities [GM01]. The details of the classifications are not relevant for this thesis. However, the information about which business capability is crucial for the business (e.g.core capabilities) and which are not (e.g. enabling capabilities), helps to prioritize EAM and APC activities. Example: Schneider and Matthes [SM14] outline that poor agility is a consequence of APC. The consequence of poor agility in *Development* business capabilities has a greater impact on the business success than poor agility in *HR* or *Taxes* business capability and thus affects the prioritization of EAM and APC activities.

2.3.3. Capability-based EAM

Freitag [Fr14] summarizes that the concept of *capability-based planning* has its roots in defense planning and transformation of military forces. In this thesis, the paradigm is only examined with regard to EAM. Although BCM represents a rather new tool in the EAM community [AH18], EAM standards [Ch11, Th17a], books [RW06, Ha13], and scientific research [BM05, BB07, PL07, BM10, Fr14, AH18] investigate the role of business capabilities and BCMs in EAM.

TOGAF outlines that *capability management is aligned with enterprise architecture* [Th17a]. As illustrated in Figure 2.9, business capabilities can be integrated in a four-level hierarchy from a business perspective. Each layer has a relationship to EAM. The related EAM artifacts – such as *Architecture Vision* – supports the definition of suitable solutions and projects. TOGAF and Barroero et al. [BM10] allocate business capabilities to the business architecture layer of EAs. However, the framework does not provide concrete best practices, examples, or methods that outline how business capabilities support EAM activities. Nor Zachman considers business capabilities in its framework [SZ92] (although Brits et al. [BB07] claim that each cell in the Zachman framework is an abstraction of the enterprise and is closely related to business capabilities). The BEAMS framework outlines an activity states that enterprise architects should constantly investigate whether their certain solution is still aligned to the allocated business capability [Ch11].

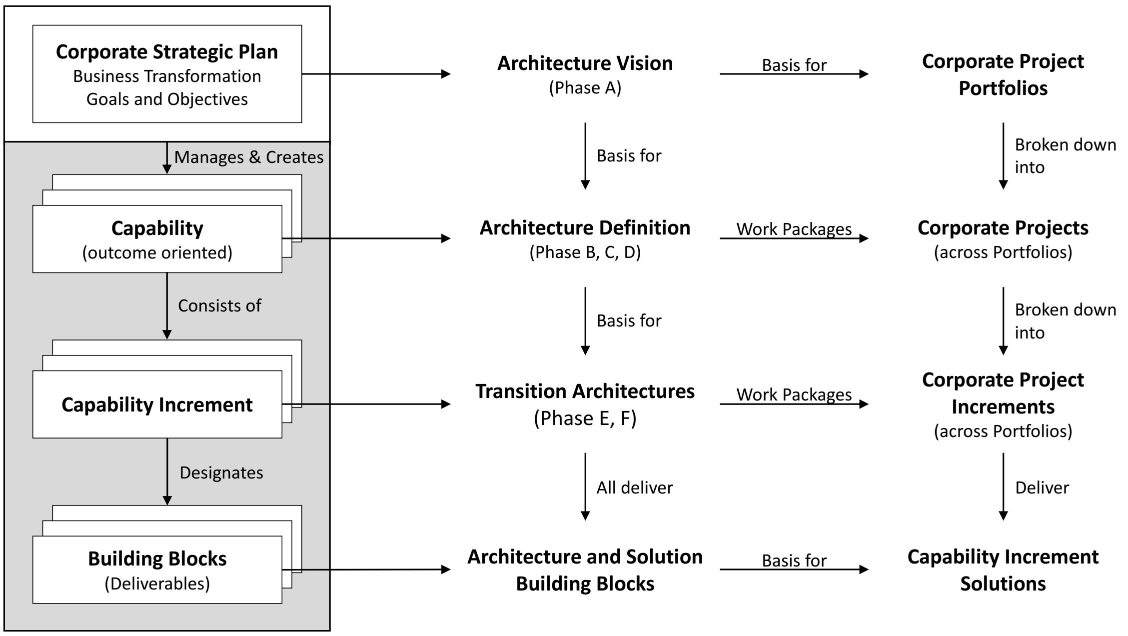

Figure 2.9.: Relationship between capabilities, EA, and projects [Th17a]

Other authors demonstrate use cases for a capability-based EAM. They can be used to provide transparency regarding certain EAM concerns by using heat maps. Based on available EA attributes, *there are hardly any limits to one's fantasy* [Ke09]. The following list shows a number of possible use cases.

- **Investment decisions:** Core business capabilities with IT gaps have a higher priority in investment decisions [Ke09].
- **IT / business alignment:** Visualize which business capabilities do not fit into the business strategy (not suitable IT support) [MB06, Ke09, BM10, Re13].
- **Outsourcing decisions:** Business capabilities that do not have any competitive advantage, but incur high operational costs, can be identified and are possible outsourcing candidates [BM05, Ke09].
- **Identify dependencies:** L0 business capabilities should have few interdependencies between each other. Interdependencies can be interfaces between applications in different business capabilities. The visualization of such interdependencies supports to derive suitable EAM actions to decrease dependencies in the EA [AH18, FM11].
- **IT cost management** By mapping the EA (including IT costs for each component) to the BCM, color coding can be used to highlight which IT costs were caused by which business capability. IT costs can be operational, project, or both [AH18].

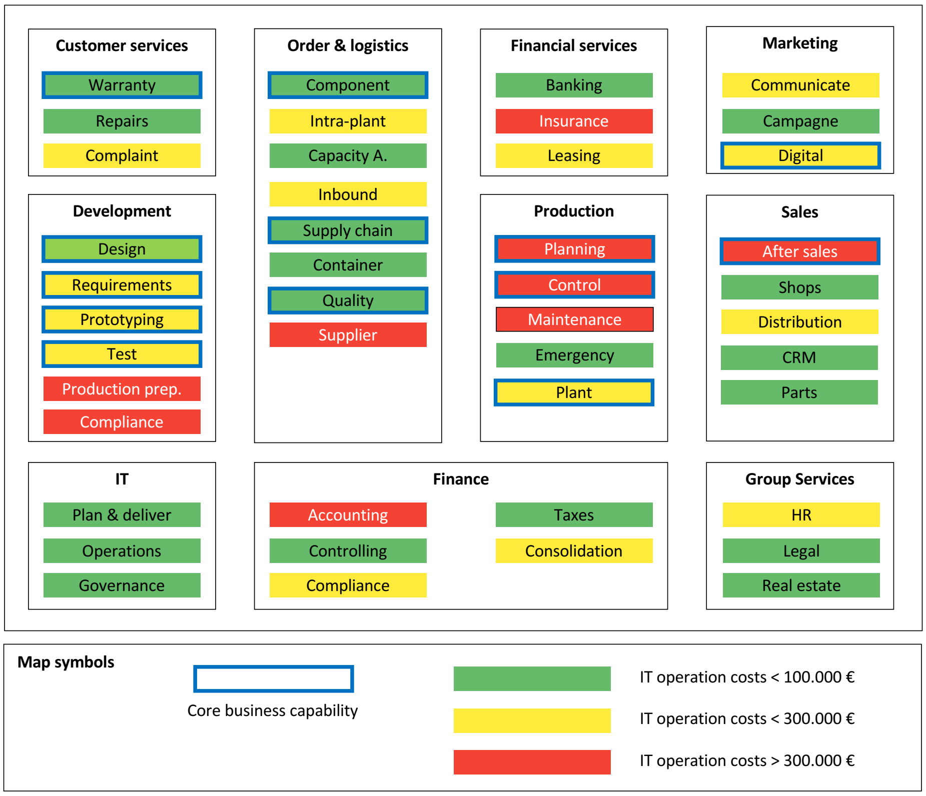

Figure 2.10.: Example of a BCM – Heat mapping to visualize IT costs

Figure 2.10 illustrates an example of BCM, visualizing IT operational costs in each business capability and core business capabilities. For instance the *Accounting* business capability incurs high IT operational costs without being a core business capability. The underlying IT architecture should be investigated in terms of cost reduction.

Our research group investigated current practices of BCM for EAM by conducting expert interviews with 25 organizations [AH18]. The aim of the study was to evaluate to which extend BCMs are used in EAM, for which purposes the concept is used, and what kind of challenges EAM practitioners face when introducing BCMs in their organizations. Figure 2.11 shows when the practitioners started to consider BCMs in their EAM practice. The statistic shows two peaks; one with two years experience and the second peak at seven years. The first peak at two years gets in line with Keller [Ke09] and shows that using BCM for EAM is still at an early stage. On the other hand, a significant number of organizations started to consider BCMs seven years ago. This could be explained by the growing popularity of EAM in the interviewed organizations: the interviewed organizations started approx. eight years ago to introduce a structured EAM methodology in their organizations and a significant number of them introduced BCMs since almost the beginning. 23 out of the 25 organizations use BCM for strategic (business IT alignment, increase agility bottlenecks, etc.) and 19 for operational (current hot spots, cost driver, etc.) purposes which reveals the multifaceted application possibilities of BCMs for EAM. We also asked the interviewees which EA attributes are mapped to their BCM. The top five named attributes are applications (23), responsibilities (14), processes (13), projects (12), IT costs, business objects, and technologies (8). Regardless of the fact that these findings show which applications and visualizations are useful for a capability-based EAM, it also shows that the alignment of the AP to the business is the most crucial factor. Further insights regarding mapping are documented in [AH18].

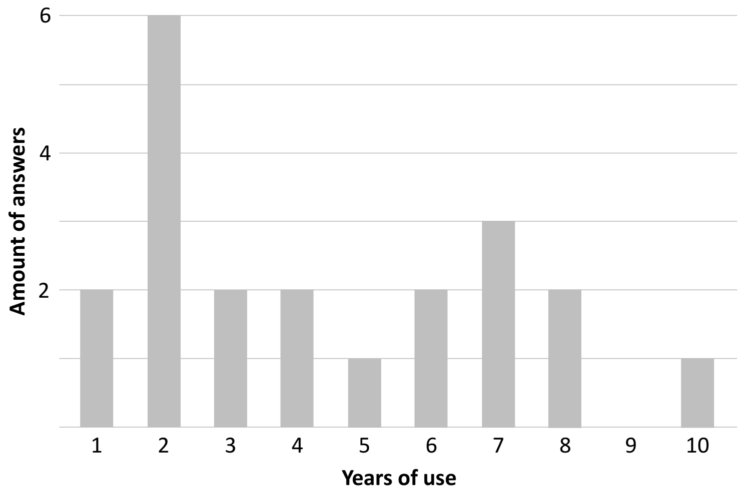

Figure 2.11.: Years of using BCMs in EAM in 2017 [AH18]

In order to use the concept effectively, it must be understood and accepted beyond EAM. Figure 2.12 illustrates the challenges. The added value is not yet recognized: practitioners complain about missing acceptance (11), missing management support (7), and missing contact persons from business departments (6). More importantly, experts explained that their BCM is not communicated well enough in their organization [AH18].

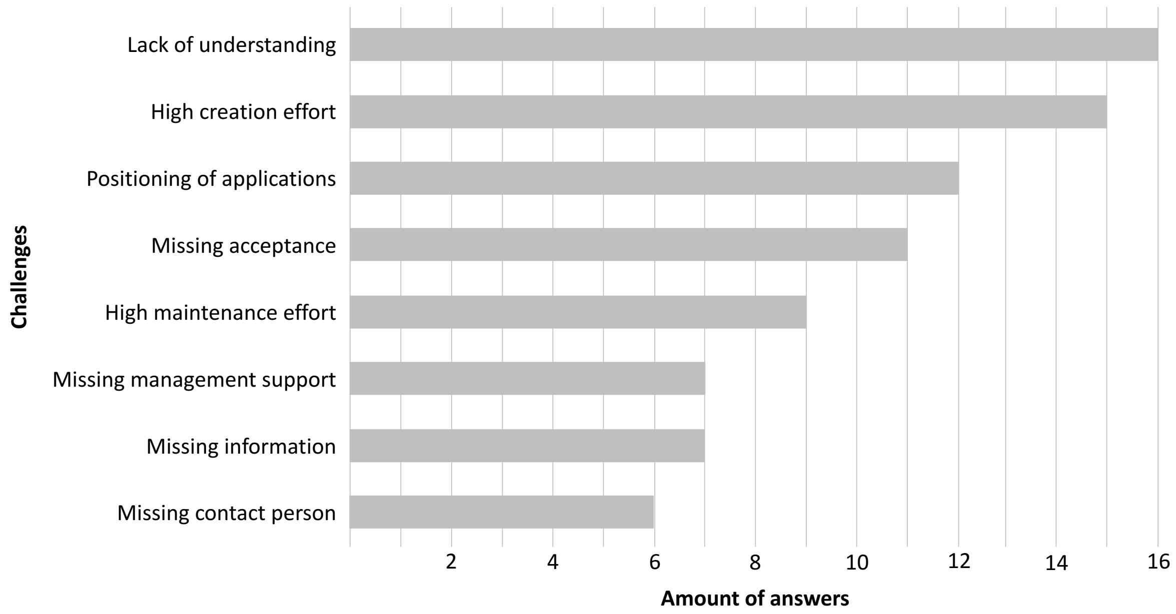

Figure 2.12.: Challenges when introducing BCM for EAM [AH18]

Although capability-based EAM is a promising approach to reveal transparency about strategic and operational issues, align the EA to the business, and serve as a communication basis between business and IT, contributions about best practices are limited. Identified contributions are presented in Section 2.4.4.

2.4. Related work

Before starting to design and subsequently evaluate the artifacts, related work of this thesis has been analyzed. The related work considers contributions to APC (cf. Section 2.4.2), APM (cf. (Section 2.4.3), and BCM for APM cf. Section 2.4.4. The section starts with an explanation of the review process, then illustrates the identified contributions, and ends with an assessment of this chapter. The assessment aggregates the mentioned foundations and related works to one common image to illustrate the research gap.

2.4.1. Literature review process

In order to investigate relevant contributions about the research area, the thesis considers a structured literature review, following the guidance of Webster and Watson [WW02]. Although research provides various possibilities to conduct a literature review [Co88, Fe06, LE06, VS09, OS10], the thesis aligns to one one method as the leading one. Based on the number of citations, the method by Webster and Watson has proved to be successful and is thus selected for the literature review. The literature review was conducted in four sequential steps and is illustrated in Figure 2.13.

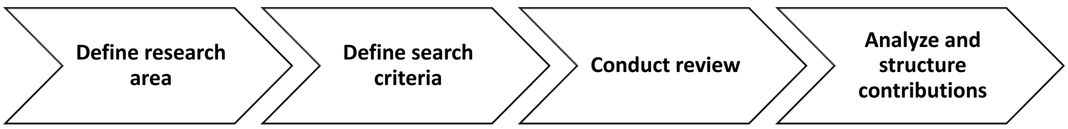

Figure 2.13.: Literature review process

- **Define research area:** Our research group identifies the emerging concern of APC in EAM and the upcoming trend of using BCM in EAM by investigating current EAM concerns and methods in practice in 2015 [AS15, AH16]. Moreover, this research was supported by the EA governance department of an automotive company, which also outlines the emerging issue of APC. Based on this input, the research area was narrowed, reflected by a hypothesis, and concertized with three RQs. Hypothesis and RQs are outlined in Section 1.1.

- **Define search criteria:** In his master's thesis, Yilmaz [Yi17] conducted a structured literature review on APM, and BCM. He defined two search queries to identify relevant contributions. First query: *"Application application evaluation" OR "Application application assessment" OR "Application application analysis" OR "Application portfolio analysis" OR "Application portfolio evaluation" OR "Application portfolio assessment" OR "Application landscape evaluation" OR "Application landscape assessment"*. Second query: *"Business capability map" OR "Business capability" OR "Business capabilities"*. The results of the queries are illustrated in Table 2.3 and 2.4. Afterwards, a third search query (*application portfolio complexity* and *application landscape complexity*) was added to his literature review which did not identify additional contributions.

- **Conduct review:** Based on the *Basket of 8* which illustrates the top journals in the IS field, the literature review focuses strongly on the respective journals. However, the review considers five well-known databases for IS contributions, also considering valuable contributions from conferences, books, and other sources. Tables 2.3 and 2.4 illustrate how many contributions were identified for further investigation. The literature review follows the best practices of *backward* and *forward* reviewing to *accumulate a relatively complete census of relevant literature* [WW02]. Although the literature review reveals a high number of relevant contributions, skimming through the articles reveals that only certain contributions are relevant for this thesis (cf. Section 2.4.3, 2.4.4, and 2.4.2)
- **Analyze and structure contributions:** Following Cooper [Co88] and Webster and Watson [WW02] the relevant contributions were analyzed and summarized with a concept-centric approach (e.g. APC, APM methods) and are explained in the upcoming sections (each concept explained in one section). In Section 2.5 all relevant concepts are aggregated to a common image.

Databases	**Search area**	**Number**
EBSCOhost Online Research Database	"TX All Text"	5
ScienceDirect	"All Fields"	6
Scopus	"All Fields"	25
IEEE Xplore Digital Library	"Full Text & Metadata"	0
ACM Digital Library	"Any Field"	9
Total:		45

Table 2.3.: Number of identified sources for search query one [Yi17]

Databases	**Search area**	**Number**
EBSCOhost Online Research Database	"Title only"	42
ScienceDirect	"Article Title, Abstract, Keywords"	25
Scopus	"Article Title, Abstract, Keywords"	241
IEEE Xplore Digital Library	"Metadata"	7
ACM Digital Library	"Any Field"	46
Total:		361

Table 2.4.: Number of identified sources for search query two [Yi17]

2.4.2. Application portfolio complexity

Mocker's [Mo09a] research is one of the first empirical evaluations of APC. Although Mocker names the phenomenon *IT complexity*, his analysis considers measures of applications and is thus situated in the area of APs. As already outlined in Section 2.2, Mocker defines APC as the manifestation of APC drivers and their effects. He further distinguishes between different types of APC: *interdependency-* (interconnectedness of an application), *diversity-* (number of used technologies to implement the application), *deviation-* (used technologies within application comply to organization standard), and *overlap-related* (degree of redundant covered functionalities) APC [Mo09a]. Figure 2.14 illustrates his conceptual model and considered characteristics. A *Cause of IT complexity* leads to a certain type of *IT complexity* and manifests itself as an *Impact of IT complexity.*

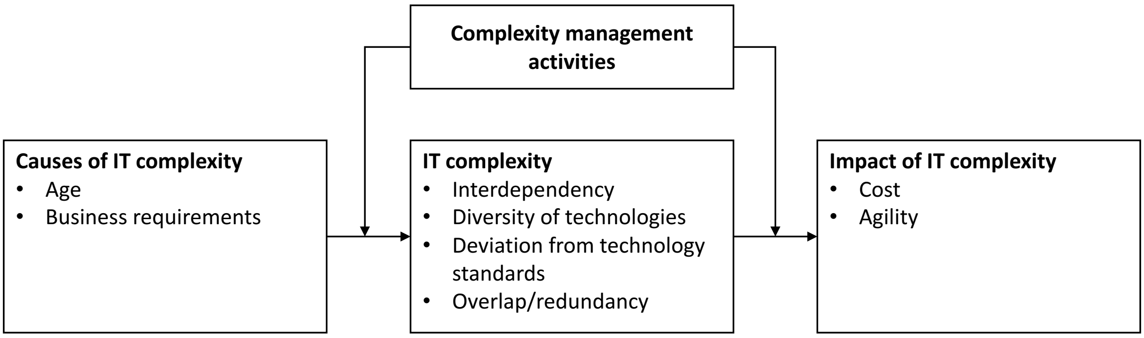

Figure 2.14.: Conceptual model of APC by Mocker [Mo09a]

Based on data from 273 applications from an investment bank, Mocker evaluates his conceptual model with a quantitative research approach (correlation analysis). His results show a linear correlation between interdependency-related APC driver and operating costs. He further outlined that future research should investigate interdepndency-related APC *by differentiating between the degree or type of interdependency between applications.* Schneider and Matthes [SM14] reveal APC drivers and their effects by conducting focus group interviews with industry experts. The result reveals five APC drivers (number of local decisions, level of business complexity, number of legal requirements, technological progress, short-term solutions) and five effects (increased costs, decreased agility, increased skill dependency, range of shadow IT, more error rates). Although their group discussion shows a very fragmented picture on APC drivers and their effects it turned out that *there was consensus in the group that heterogeneity of application. Nevertheless, it has been decided that heterogeneity—and therefore diversity—is an inherent part of complexity (as is the amount of application landscape components) and can therefore be excluded from the drivers and consequences list.* [SM14]. In contrast to Mocker, Schneider and Matthes consider organizational APC drivers and effects rather than focusing on architectural characteristics.

While the approach by Mocker and Schneider and Matthes considers various APC drivers and effects of APs, Schuetz et al. [SW13] introduces a portfolio-related metric to measure the complexity of EAs. They claim that EA complexity, adopting to any EA layer, is characterized by the number of components and the relations among them [SW13]. Based on that, they define a entropy-based measure that evaluates the heterogeneity of a component group (e.g.

databases) considering their diversity (e.g. different types of employed database technologies) and balance (e.g. distribution among databases instances). They evaluated the applicability and benefit of the measure with data from a company in the financial sector. The same approach was evaluated by Schneider et al. [SR15] with data from four companies. Besides the entropy-based measure, they evaluated two further metrics: a topology-based metric by Lagerstroem et al. [LB14] and six further metrics that they identified in a workshop with six companies. All three approaches (entropy-based, topology-based, and industry metrics) were evaluated through quantitative analyses on each dataset of the four companies. Their results reveal that the heterogeneity-based metric suits good to measure the complexity of the infrastructure layer, the topology-based metric to assess the criticality of change projects, and industry metrics to predict costs increase transparency.

The topology-based approach adopts the *hidden structure method* from software engineering to discover hidden structures (*facts about the applications and their relationships*) [LB14]. The AP is visualized in a graph in which the nodes illustrates elements – in our case applications – and edges information flows. Based on the number of transitive dependencies, each architecture can be classified as core-periphery, multi-core or hierarchical. Past research only reveals core-periphery architecture. In such a case, each element (application) can be associated to one of four categories: *1) one large cyclic group, called the Core, 2) "Control" elements that depend on other elements but are not themselves used by many, 3) "Shared" elements that are used by other elements but do not depend on that many other, and 4) "Periphery" elements that are not used by or depend on a large group of other elements* [LB14]. Based on this classification, a so called propagation cost metric propagates what percentage of the applications will be affected when changing one random element in the AP. They evaluated their method in a telecommunication case with data of 103 applications and 243 dependencies. Their results show a propagation cost of 25%. For further information about the method, the architecture types, and the propagation cost metric, we refer to the respective contribution. However, limiting the approach to only an AP reveals how interdependencies between applications, such as an AP driver, contributes to costs as an AP effect.

Beese et al. [BA16] and Schilling et al. [SB17] also analyzed complexity in the IS sector and their effects in the EA, whereas their research investigates IT complexity effects in terms of IS flexibility, efficiency, and outcomes, rather than concrete application characteristics (IT costs, incident tickets, etc.). Both studies investigated IT complexity with a partial least squares approach. Beese et al. contributes a structural equation model that outlines to which extend complexity drivers (Diversity, Size, Planning, Integration, Dynamics) contributes to complexity effects (Efficiency, Agility, Comprehensibility, Predictability). Their model also differentiates between structural and dynamic complexity and reveals that *Structural complexity is mainly driven by inadequate planning, whereas dynamic complexity is mostly the result of a high structural complexity combined with strong dynamics*. Schilling et al. also contributes a structural equation model and revaled that *there is both, (i) a significant direct negative relation between IS architecture complexity and IS architecture outcomes without mediation, as well as (ii) no significant relation between IS architecture complexity and IS architecture outcomes when considering additional mediation effects through IS change.*

The aforementioned contributions are related to the topic of this thesis to such an extent that they show how complexity drivers and effects interact in practice. Other contributions study APC from a conceptual perspective. Schneider et al. [SZ14] provides a notion which classifies EA complexity in four different dimensions. One dimension distinguishes between *objective* and *subjective* complexity: a system can be complex by its nature or architecture and is not affected by any observer, like the mass of a physical body leads to a certain weight by nature (objective complexity). On the other hand, a system can be viewed as complex by an observer, for instance a user views an application as complex because of a confusing user interface (subjective complexity). Schneider et al. provide three further dimensions: *organized* vs. *disorganized*, *qualitative* vs. *quantitative*, and *structural* vs. *dynamic* complexity. Although the notation does not provide concrete insights on APC indicators, the contribution does show that system complexity can be observed and addressed from different angles.

In a further contribution, Schneider [Sc16] introduces a conceptual framework which describes AP diversity. Since diversity is a major driver for complexity [Sc16], the framework provides four dimensions that should be considered when designing or transforming an AP: *Variety, Disparity, Balance,* and *Variation.* Figure 2.15 illustrates the framework.

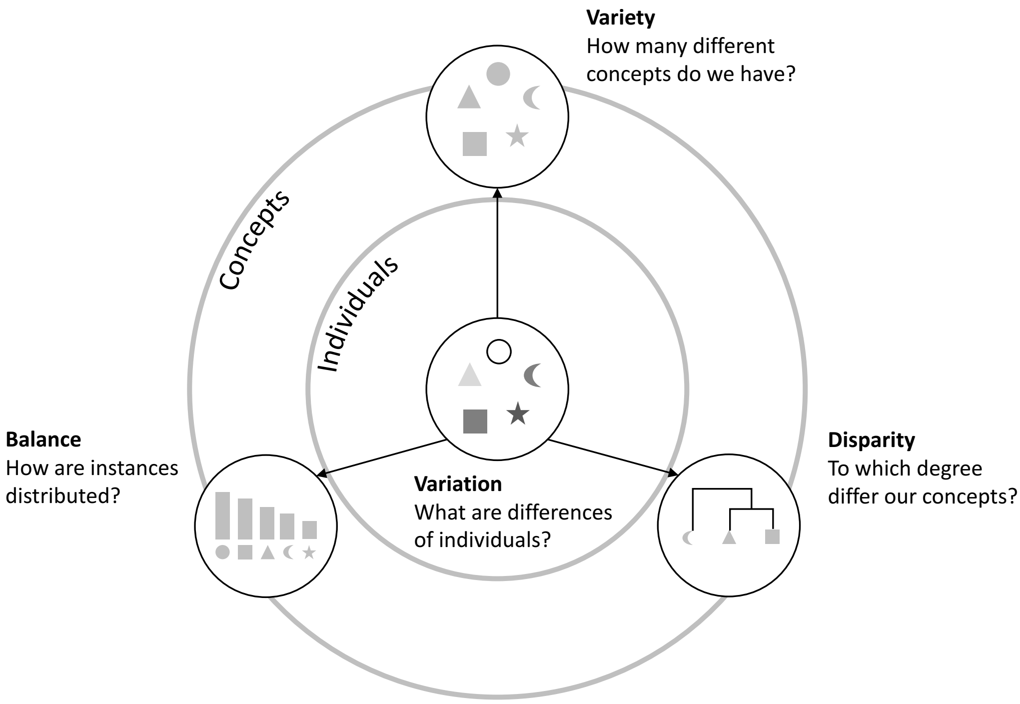

Figure 2.15.: Application architecture diversity framework by Schneider [Sc16] (simplified)

Schneider defines ***Variation*** *as diversity within a concept* [Sc16]. In the AP context, a concept could be SAP[1]. Example: an organization runs four SAP systems, all considering different modules, table schemes, and further differences. Each SAP system illustrates an individual. Schneider states that a healthy population between individuals of the same concept is crucial

[1] Multinational software corporation (full name: SAP SE) that develops enterprise software solutions

for the *adaptability and robustness of complex systems* [Sc16]. ***Variety*** explains how many different concepts are used in the ecosystem. For instance Microsoft Dynamics enterprise resource planning (ERP)[2], SAP, and, Oracle E-Business Suite[3] as three different concepts that an organization offers for use. The healthy population of options affects AP diversity. The third dimension is ***Balance*** which can easily be attributed to the heterogeneity metric of Schuetz et al. [SW13]: in general we claim that low heterogeneity – so a normal distribution of instances for the same type of component – leads to reduced APC. The fourth dimension is ***Disparity*** which describes differences between concepts. Example [Sc16]: For instance an organization offers IBM DB[4], Oracle DB[5], and Mongo DB[6] for use. Since MongoDB is the only database technology that does not follow a relational database and is not supported by large vendors, this database technology differs strongly from the other both concepts and thus leads to a high disparity.

Although Schneiders framework provides four conceptual dimensions of AP diversity, rather then of APC, the contribution provides a further view on how to look at the phenomenon. Further research by Janssen and Kuk [JK06] Saat et al. [SA09], Kandjani et al. [KB12, KB13] investigate the term complexity in an EAM context, however their research objectives are too far from the subject of this thesis. I refer to the listed articles. In line with Schneider and Matthes [SM14] and Mocker [Mo09a], in this thesis APC is characterized by the manifestation of APC indicators. Thus the literature review considers the identification of APC indicators. The identified indicators – illustrated in Table 2.5 – are crucial for the design of the artifacts. The subsequent explanation of the APC clarify why the respective indicator affects APC. For further information about the indicators and measures, I refer to Yilmaz's master thesis [Yi17].

- The **number of interfaces** is the most mentioned indicator in literature. It illustrates the number of connections of one application to others and thus the degree of interdependency. Every change to an application might affect connected applications as well. The more interfaces an application has, the greater the risk of additional changes in the AP.
- **Capability coverage** counts how many different business functions, in this thesis business capabilities, are supported by an application. It appears likely that functional changes to a business capability, for instance new business requirements, affect the underlying applications. The more business capabilities are supported by an application, the more business driven changes have to be considered by an application.
- The **application age** considers the elapsed time since the initial go-live of the application. It is likely that older applications rely on outdated technologies, provide security risks, and are highly customized. These characteristics require higher expenses in case of application changes or maintenance.
- **Technical diversity** indicates on how many different technologies the application relies on. Higher technical diversity leads to higher heterogeneity.

[2]Microsoft Dynamics ERP is a software solution by Microsoft Corporation
[3]Suite of corporate software solutions by Oracle Corporation
[4]Database solution by company IBM
[5]Database solution by Oracle Corporation
[6]Open source database solution by Mongo DB Inc.

APC indicator	Source
Number of interfaces	[RW06, Mo09a, La08, Ki13, SW13, SR15, SW13, AB16]
Capability coverage	[MS02, Mo09a, SW13, Vo15]
Application age	[RW06, Mo09a, Be14, SS16]
Technological diversity	[Mo09a, SW13, Vo15, SR15]
Functional coverage	[La08, SW13, Vo15, SR15]
Deviation from standard	[BV09, Mo09a, SR15]
Application failure	[MS02, VS07]
Application size	[MS02, VS07, BV09]
Functional overlap	[Mo09a, Vo15, SR15]
Documentation	[MS02, BV09]
Technology age	[BV09, Sc16]
Number of incidents	[La08, Mo09a]
Operating costs	[La08, Mo09a]
Number of users	[La08, AB16]

Table 2.5.: Overview of identified application characteristics from literature review (based on [Yi17])

- In contrast to capability coverage, the **functional coverage** illustrates how many business functions are considered in one single application. Applications that aggregate multiple business functions decreases the modularity and consequently the agility of the AP.
- **Deviation from standard** indicates if an application complies with standard specifications of the organization. An example would be the use of dedicated database technologies. Applications that does not comply with standards of the organization require additional resources for maintenance and efforts for changes and thus increase the cost of the AP and decrease its agility.
- An **application failure** illustrates the robustness of an application. A high amount of application failures lead to additional expenses for fixing. The higher the amount of vulnerable applications in an AP, the greater the expenses.
- The **application size** shows the scope of the application, for instance by lines of code or function points. It is likely that large applications have more dependencies (internal between modules or external by interfaces) and decreases the agility of the AP.
- When two applications support the same business function, process, or capability, we are talking about redundancy or a **functional overlap**. A highly functional overlap increases the operational costs and decreases agility.
- The quality of application **documentation** affects the transparency of the application setup and structure. Lack of transparency leads to additional efforts in change projects and thus decreases agility and increases costs of the AP.

- **Technology age** considers the age of used technologies in an application – for instance the used programming language. Older programming languages may have a more complex syntax and may affect the agility of an application in a change project. Decreased agility of applications affect the overall agility of an AP.
- The **number of incidents** is an AP effect. Applications with a high amount of incident tickets incur higher maintenance costs and lead to higher costs of the AP.
- The **number of users** illustrates how many users are using a certain application. The higher the amount of users of an application, the greater the effects of changes within an application in the organization and thus the importance of the application. Failed changes of applications with a high amount of users affect more users. In addition to that, applications with a high amount of users have to cover business requirements from multiple users and thus leads to further expenses in change projects. The higher the amount of such applications in an AP, the greater the change costs of an AP.
- The **operating costs** of an application is an AP effect. Applications with high operating costs lead to higher AP operating costs.

2.4.3. APM approaches

Based on Gibson and Nolan's idea to manage the lifecycle of applications within a portfolio [GN74], APM attracts more attention in research and several APM approaches evolved over time. At its heart, APM analyzes APs with a matrix-based approach to investigate the health, heterogeneity, business value or any other view depending on certain application characteristics [SF10]. While there is a broad range of contributions that investigate application characteristics for portfolio analysis [MH05, De09], the benefit of portfolio analysis for IS and APs [KV03, Ca07, MS10] or the impact of portfolio complexity [SD00, GS05, Mo05], this section aims to outline what current APM approaches look like and how this thesis can be positioned in APM research.

The subsequent sections will outline four recent APM approaches from research. The section ends with a comparison of the approaches and an investigation into how APM research will benefit from this thesis.

2.4.3.1. AP health assessment by Weill and Vitale [WV99]

Weill and Vitale introduce a model to measure the *health* of an AP. The health of a system (equivalent to application) is characterized by five dimensions: importance, investment, technical quality, use, and management value. At this time, Weill and Vitale argue that the assessment of an AP as a whole is of great importance and helps to reveal concrete issues in the AP, support the IS planning process, optimize IS investment decisions, and implement business requirements more effectively. The model proposes a visualization by using a health grid. Figure 2.16 illustrates a health grid, based on a case study (AP data and expert interviews) with a multinational process-manufacturing company.

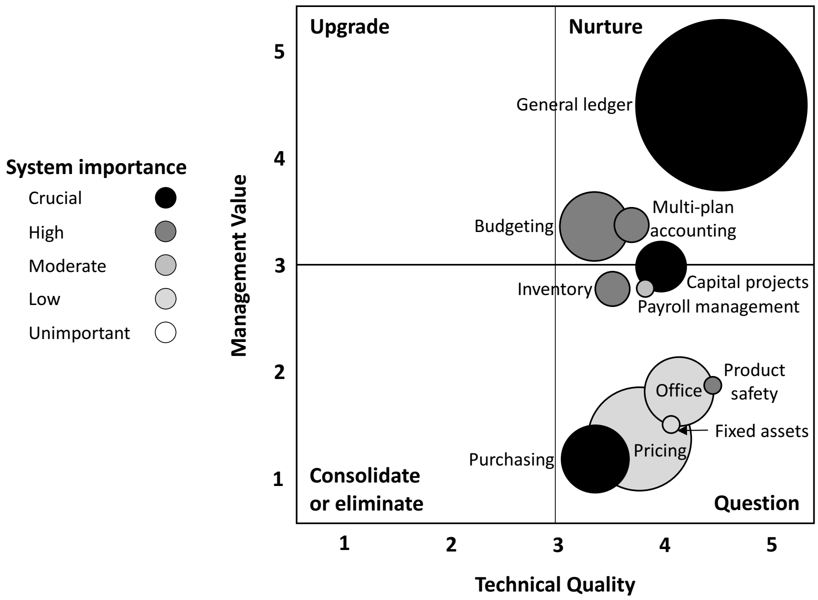

Figure 2.16.: Application portfolio health grid by Weill and Vitale [WV99]

Every application is evaluated regarding the five dimensions, based on qualitative judgments from the expert interviews. After that, every application (illustrated with bubbles) is allocated to one quadrant (*Upgrade, Nurture, Question*, or *Consolidate or eliminate*). The size of the bubble indicates the costs (development and operating costs per year) and the color the importance of an application. Further details of the case study and the five dimensions of an AP health are documented in their contribution [WV99].

Based on the allocated quadrant, different management actions are required. The quadrants have the following meanings:

- **Nurture:** Applications in this quadrant are the *life blood* of the organization [WV99]. Keeping these applications running and maintained has high significance.
- **Question:** Although the applications in this quadrant are of good technical quality, the management value is low. Perhaps some applications can be modified to generate added management value. Otherwise these systems could be candidates for elimination.
- **Upgrade:** These applications generate high management value but are of low technical quality. A time-out of these systems may lead to business issues and should be investigated to increase their technical quality.
- **Consolidate or eliminate:** Applications of low technical quality and management value are candidates for consolidation or elimination.

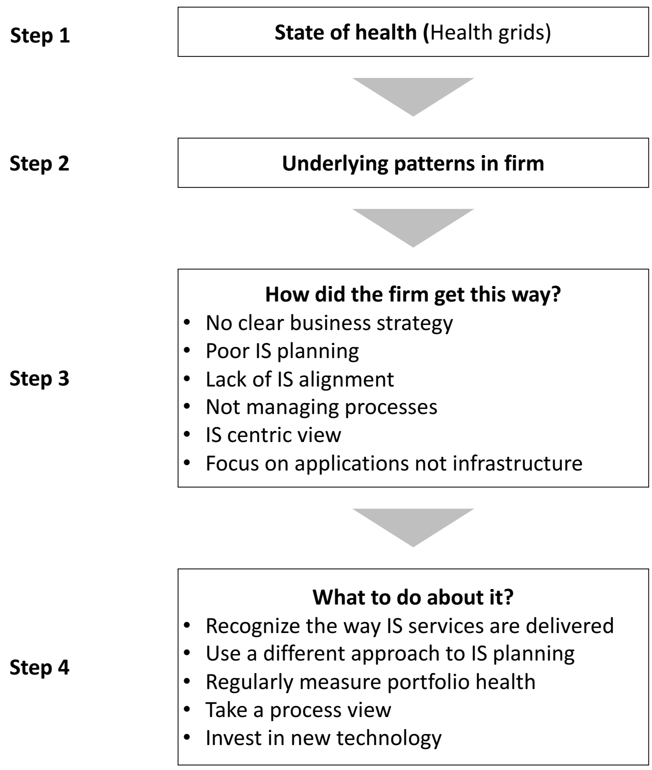

Figure 2.17.: Steps to improve the health of an AP by Weill and Vitale [WV99]

The creation of the health grid is the first step of Weills and Vitale's model to increase AP health. Figure 2.17 illustrates the further steps to improve AP health. In the second step, the organizations should investigate every grid and its applications to identify patterns in their organization (for instance identify applications from a certain business department or with the same technology frequently in the same quadrant). In the next step, the organization tries to identify root causes for this situation. In the last step, concrete actions have to be derived.

2.4.3.2. AP rationalization by Farbiek et al. [FB07]

In line with Weill and Viatle [WV99], Fabriek et al. [FB07] introduce an AP rationalization method. They define AP rationalization as a process that *aims to analyze and restructure the complete set of applications in an organization* and as *activities that are applied to reduce portfolio complexity* [FB07]. Their method consists of three process steps and each step of two or three activities. Figure 2.18 illustrates the method.

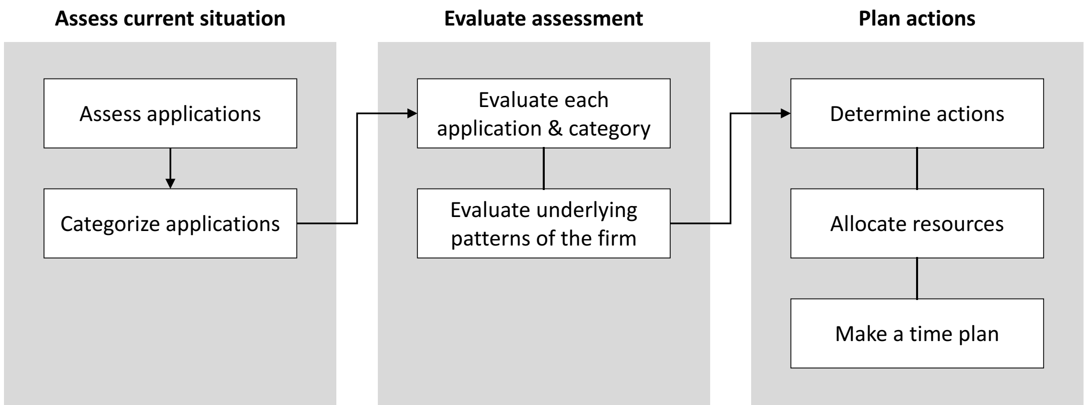

Figure 2.18.: APR method by Farbiek et al. [FB07]

At first the organization has to **assess the current situation** by collecting and categorizing all relevant application information within the AP. After all relevant applications are identified, they propose to *assess applications* by defining the business value of each application (value for business unit, of use, management technical, and investment value). Subsequently, they *categorize applications* by e.g. shared vs. commonly used applications, programming languages, investment cluster, or following the four proposed quadrants by Weill and Vitale [WV99] (cf. Section 2.4.3.1).

In the next phase (**evaluation assessment**) all applications in each category are evaluated to identify inefficient entities (e.g. low technical quality and high management value, or high application investments with low management value). Each category should follow its own rules (example: in category A over 500.000,- per year illustrates high investment for an application and in category B the investment threshold is at 100.000,-). Based on the set of inefficient applications, the organization can start to identify underlying patterns (IT/business alignment of applications, poor technical architecture, etc.).

The AP insights are used to **plan actions** for inefficient applications (change, invest, remove) and IT management (redesign IT strategy, increase communication between business and IT, etc.) and allocate resources for short- and long-term actions. The planned changes should be documented and then communicated across all relevant stakeholders in a time plan. Fabriek et al. [FB07] evaluated their method in a case study with a financial service company. The respective AP consisted of 900 applications and they identified 334 inefficient entities. It turned out that a high customization rate (70%) and insufficient technical quality of the applications were the main concerns of the AP. Based on these findings, they came up with suitable actions for the AP.

2.4.3.3. APM model by Simon et al.[SF10]

In line with Gietema et al. [GB12], Simon et al. [SF10] define APM as continuous discipline which aims to reduce complexity of APs. They introduce a model which comprises four distinctive phases. Figure 2.19 is a simplified illustration of their approach.

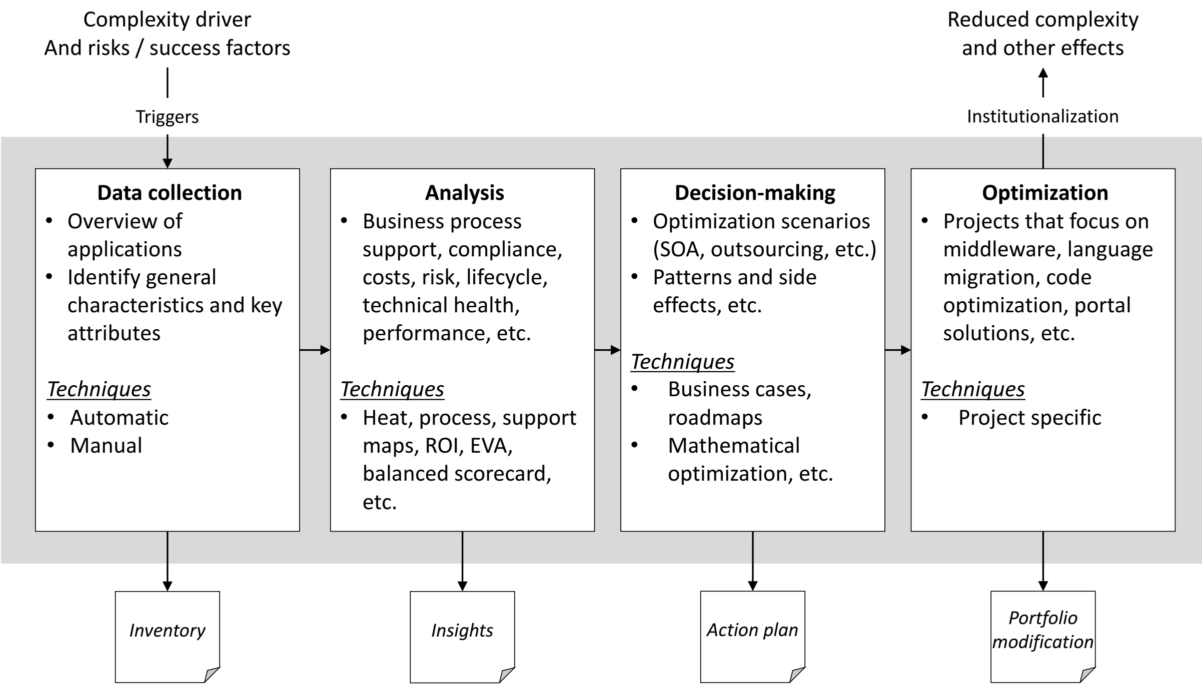

Figure 2.19.: The integrated APM model by Simon et al. [SF10] (simplified)

Based on their assumption to reduce APC they consider APC drivers, risks, and objectives as the main trigger of their APM model. The **Data collection** phase aims to capture the current state of the AP. The data collection should not simply name all operating applications within the organization, but rather key characteristics and attributes of every single entity in the portfolio - such as release version, implementation data, key capabilities, operating system, costs, vendor, etc. The information is important for the subsequent analysis and helps to understand the role of each application in the portfolio. They propose automated- (extract information from dedicated repositories), semi-automated- (extract data from various repositories followed by a data cleansing process), and manual (interviews, surveys) data collection techniques. The deliverable of this process step is a data-cleansed inventory of the AP.

The AP inventory is the starting point of the **Analysis** phase. The purpose of the analysis is to gain insights about the present AP – such as the strategic fit of an application, overview of supported business processes, main AP cost driver, the technical health of the applications, etc. Simon et al. suggest certain analysis techniques to ensure a portfolio view within the analysis. Heat maps, portfolio matrices, balanced scorecards, etc. analyze the AP as a whole rather than each dimension separately.

Based on the AP insights, the organization starts with the **Decision-making**, which aims to plan and shape the future portfolio. The organization should decide which applications should be removed, changed, or invested in. For high-level decisions, roadmaps or time-lines are well suited; for decisions based on all application characteristics and attributes, it is recommended to work with mathematical optimization models. The deliverable of this process step is a action plan. In the last step, the planned initiatives are put into action. Based on the target state of the AP, larger projects have to be set up. These projects may focus on code optimization or language migration. The continuous repetition of the process (collect, analyze, and evaluate data of applications) ensures a high maturity of the AP.

2.4.3.4. AP rationalization by Gietema et al. [GB12]

Based on literature research and several case studies Gietema et al. [GB12] introduce an AP rationalization method, whereby the authors focus on AP cost reduction. The multiple case studies with Dutch municipalities have shown that the main issue of the current AP rationalization method is *not keeping a complete overview of the application portfolio.* As a result, a lot of information about the AP is not available and there is no basis for decisions. Based on the findings from the case studies, Gietema et al. introduce a method, which does not consider AP rationalization as a one-shot project but rather as a continuous discipline to ensure a permanently optimized AP. The method consists of six process steps, each of them considering several activities. The first three steps (**(1) Assess current situation**, **(2) Evaluate**, **(3) Rationalize**, **(4) Update**) are quite similar to the proposed approaches of Weill and Vitale [WF06] (cf. Section 2.4.3.1), Fabriek et al. [FB07] (cf. Section 2.4.3.2), and Simon et al. [SF10] (cf. Section 2.4.3.3).

However, with activity five and six, the method goes one step further: before updating the AP, the organization should check if the rationalized AP suits to the target specifications in terms of arbitrariness of decisions and their communication within the organization, standardization level of the AP, and APM corporation practices. The fifth process step (**(5 Optimize application portfolio)**) acts as a kind of quality gate before updating the AP. The sixth step (**(6) Process request change**) reflects the continuity character of the method. Every proposed change to the AP, in particular add, change, or remove an application, should be checked on its benefit and effect on the AP. When the proposed change does not add any new functionality to the AP or does not match AP target specifications, the request should be declined.

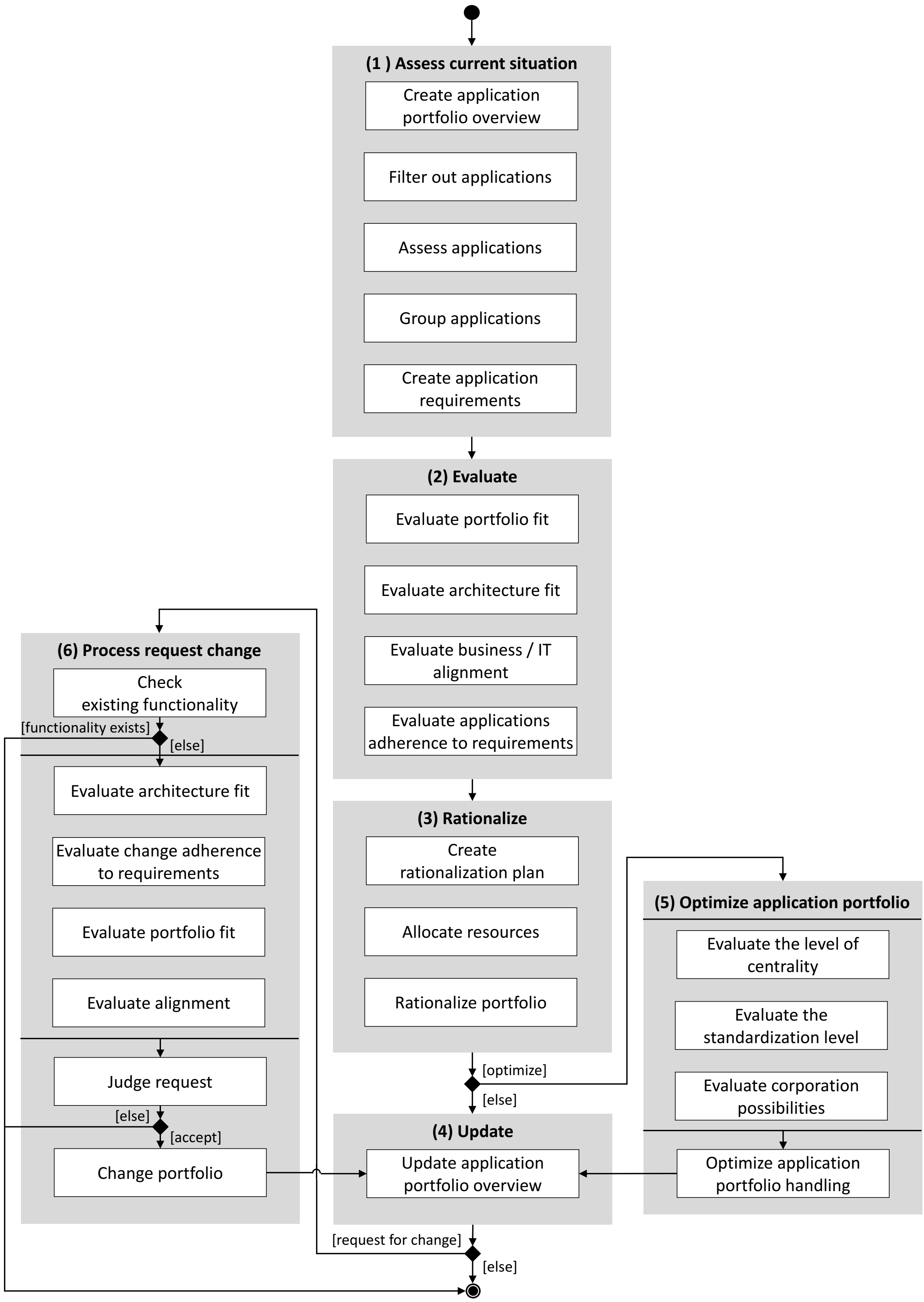

Figure 2.20.: APR method by Gietema et al. [GB12]

2.4.3.5. APM by McKeen and Smith [MS10]

Although McKeen and Smith agree with related work that APM is simply the assessment, evaluation, and optimization of APs, they shed light on this discipline from a different perspective. Based on focus group interviews with senior IT managers from different industries (financial, food, pharmaceutical, government, automotive, consulting services, retail, and telecommunications), they emphasize that three fundamental capabilities are crucial for a successful APM: strategy and governance, inventory management, and reporting and rationalization.

- **Strategy and governance:** APM is introduced for a certain purpose such as reduce APC, remove unused applications, or align the AP to the EA strategy. For whatever reason APM is introduced; organizations should define a concrete business case for their initiative. Otherwise, no stakeholder is really interested in paying for it. The involvement of business stakeholders is crucial and depends on a well-defined business case. The authors argue that *if APM is attempted solely within the IT organization without business backing, it is less likely to produce the full range of benefits.* Furthermore, organizations should define clear governance structures within APM: decisions should follow a structured framework (what, who, how) and be managed by a central governance team, rather than on a piece-meal basis.
- **Inventory management:** Based on APM strategy, organizations have to define what kind of applications should be considered in their APM initiative. Although they could consider all implemented applications, they could also focus on business-critical, cost-intensive, or monolithic applications. A focus shapes the purpose of the APM, decreases effort, and its management complexity. After that, an organization can implement a focused inventory and decide which application attributes are relevant and which are not (cf. Table 2.5 for possible application characteristics). An arbitrary implementation of an inventory is ineffective, time-consuming, and expensive.
- **Reporting and rationalization:** Once the inventory has been implemented, the organization should define suitable reports. Information demands vary by stakeholders: for instance the revision department is interested in compliance issues of applications, IT operations focus on the number of incident tickets per application, and IT management about the balance of business value and IT costs per application. The authors provide an example of with visualization which goes in line with the health grid of Weill and Vitale [WV99] (cf. Figure 2.16). However, the key message is that organizations should define suitable reports and visualization for certain information demands.

Even if the work of McKeen and Smith does not specify a method, it outlines fundamental capabilities that are crucial to succeed with APM. It shows that an arbitrary implementation of an APM method can fail and that a handful of questions, objectives and guidelines need to be clarified in advance. In particular, the emphasis on governance guidelines and the focused inventory development sharp what kind of applications should be assessed, which should be considered when evaluating the applications, and how far the planned actions align with the APM purpose.

2.4.3.6. Added value of APM approaches by this thesis

Although there are many more APM approaches, especially from practitioners [Ke09, Kr09, Wy09, SK11], most APM approaches share a similar pattern: they suggest to (1) assess the AP, (2) evaluate the applications, and (3) plan actions. Although some contributions consider certain techniques for the analysis [SF10] or consider process steps for continuous optimization [GB12], all presented approaches match this pattern. The fact that all presented approaches share this pattern indicates that this approach will probably be right. The aim of the comparison is not to criticize this approach, but rather to clarify how the contributions of this thesis enrich present APM approaches.

Figure 2.21 aggregates the presented APM approaches in a common view and highlights which activities are enriched by the produced artifacts. The purpose of the artifacts in this thesis is to support enterprise architects in capturing the status of APC indicators by using capability-based visualizations.

Weill and Vitale [WV99] determine the health of APs by allocating applications into one out of four quadrants in a 2-dimensional coordinate system – called a health grid. Although the visualization considers the technical quality, the management value, the importance, and the size of an application, the health grid does not consider certain APC indicators. Fabriek et al. [FB07] outline more application characteristics during the assessment and evaluation of applications, but does not focus on APC drivers. They also consider the health grid as the chosen visualization. Simon et al. [SF10] name certain visualization options – such as heat maps, process support maps, or portfolio matrices – but keep it on that level. A definition of concrete visualizations to address APC indicators is missing. Although McKeen and Smith [MS10] do not provide a concrete APM method, the contribution define three crucial capabilities for a successful APM initiative. The artifacts of this thesis enriches their third capability (*Reporting and rationalization* by providing concrete visualization to address the status of APC indicators.

Figure 2.21 summarizes the contribution of this thesis to APM research, compared to the outlined APM approaches. A broader positioning of this thesis (EAM as a broad field of research) is presented in Section 2.5.

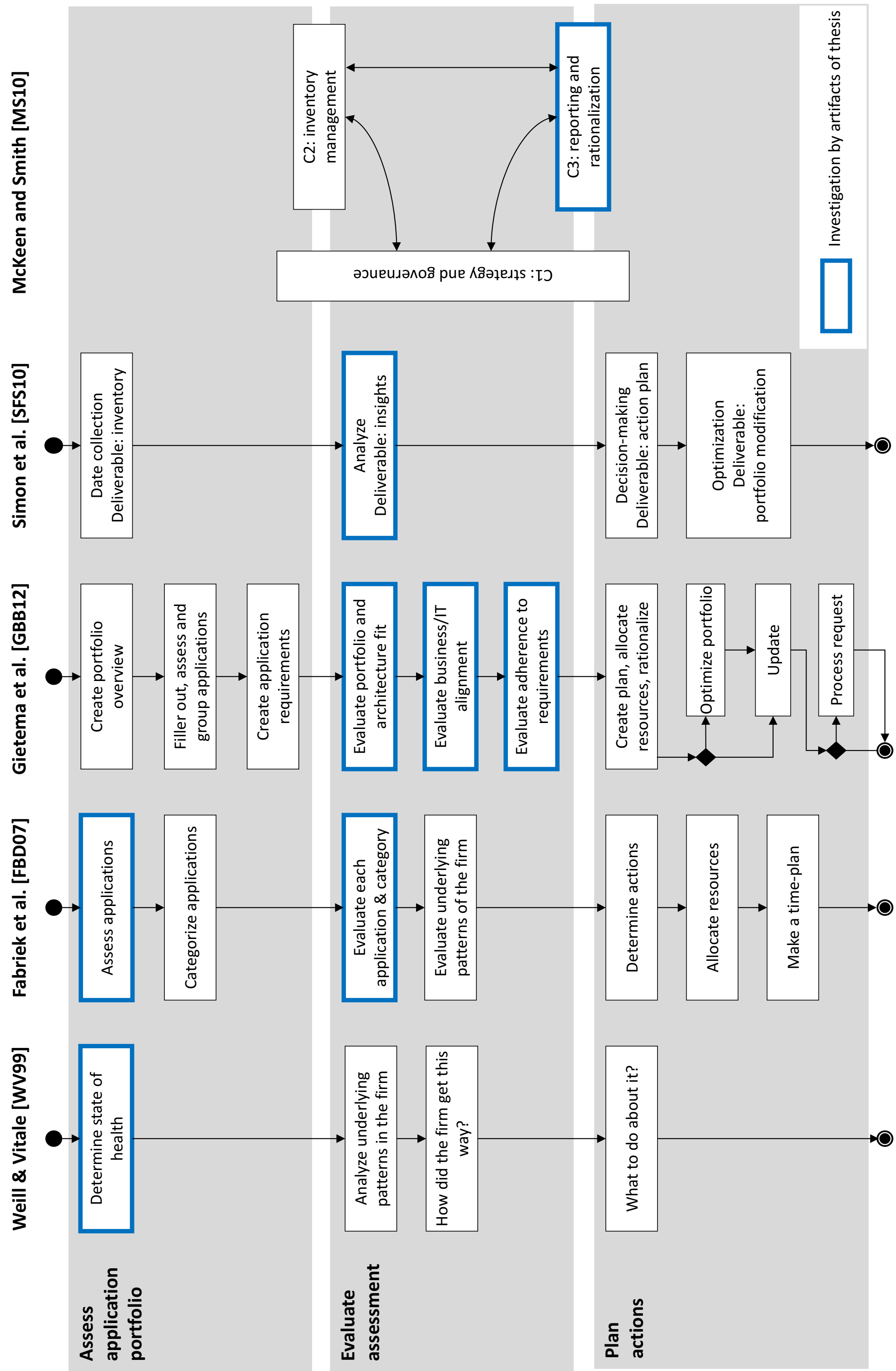

Figure 2.21.: Comparison of APM approaches (based on [Yi17])

2.4.3.7. State of corporate APM and APC practices

Since this thesis focuses on a problem that has its root in practice, it is worthwhile to review how practitioners operate APM and how they define APC. Especially consulting companies provide several solutions for APM. For instance, IBM provides a process that supports practitioners in their APM [IB12]. Although their process comes close to the presented approach within Section 2.4.3 ((1) assess the AP, (2) evaluate the applications, etc.), they do not provide detailed information for the single process steps, which data is needed, and how their process definition addresses AP complexity management. In a further document, they name *unwarranted complexity* within an application inventory as a problem that should be addressed with APM, but do not provide further information [Kr11]. A further practical-oriented solution is provided by Cognizant Technology Solutions GmbH [MS14]: in their contribution they provide a process definition to assess the health of an AP and a matrix view to illustrate misalignment's of an AP. Although they name different characteristics of applications that should be considered during the assessment (e.g. size, technical health) they only provide limited information on relevant application characteristics for the assessment. A further contribution by Scape Consulting GmbH provides more detailed information on how to measure the complexity of an EA [Sc13]: In their publication, they mainly discuss the heterogeneity of EAs and define an equation for measuring the degree of EA heterogeneity. Concrete characteristics that are required for the measurement are also named (number of used technologies, distribution of used entities among the used technologies). Further insights of other APC indicators and on how to visualize the results of the equation are not considered.

Considering suitable visualizations for APM, today's EAM repository products such as LeanIX[7], iteraplan[8], or Alfabet 10[9] provide several visualizations to illustrate the AP status from different viewpoints. LeanIX in particular addresses capability-based visualizations in their solution [Le17]. Although relevant AP indicators are addressed in their tool (application age, functional overlap) and can be visualized on a BCM, their solution is primarily an EA repository tool. Dedicated visualizations for APC management or aspects focusing on dedicated APC indicators are not provided. The contributions of practitioners can provide an initial impulse for APM or APC management, but lack of concrete APC indicators that can be considered in an APM or APC reduction initiative and how suitable and capability-based visualizations might look like.

Our research group conducted an exploratory case study with 10 experts of an automotive company to reveal root causes and consequences of APC and outline solutions to address the root causes of APC [AB16a]. Our case study reveals both technical (e.g. source code complexity, quality of interfaces, design of data flows) and organizational (capacity, IT authority of business, role allocation) root causes are named in practice for APC. Consequences are e.g. unnecessary efforts to handle IT operations, lack of data quality and performance issues. The experts did not name an APM standard process as a solution but rather pragmatic approaches, such as increase the capacity, conduct code reviews or provide a pool of experts. A regulated APM or APC management approach does not exist.

[7]EAM tool by LeanIX Inc.
[8]EAM tool by iteratec GmbH
[9]EAM tool by Software AG

2.4.4. Relevance of BCMs in EAM and APM

Even though various contributions about BCMs have been identified during the literature review and using BCM for EAM is already discussed by researchers and practitioners (cf. Section 2.3.3), the investigation reveals that using the concept in EAM, APM, or APC management practice is at the very beginning (cf. Figure 2.11). The concept originates from the *Theory of Firm* [Sp09] and has its roots in economics. Accordingly, most of the identified articles investigate BCM for economic research rather than for EAM or APM visualizations. Nevertheless, there are a few recent works on this subject which are briefly described here.

- **Keller [Ke09]:** Keller addresses the topic at an early stage and reveals that a BCM can satisfy both technicians and business managers. He explains that *Capabilities are not just technology but cover all aspects: People, processes and the technology used to support them* and capability-based visualizations provide high level information for business managers and drill-downs for technicians. He demonstrates the capability-based EAM approach with heat maps and names three deployment scenarios: *Investment decisions*, *IT/business alignment*, *Outsourcing decisions* and *IT demand management*.
- **Sykes and Clayton [SC12]:** Sykes and Clayton use the BCM to visualize business value and the level of IT investments for each business capability. They simultaneously visualize both characteristics of the BCM (capability surface for business value and capability border for level of IT investments). Figure 2.22 shows a simplified example of their simultaneous concept. The heat mapping supports upper management stakeholders to decide on future IT investments.

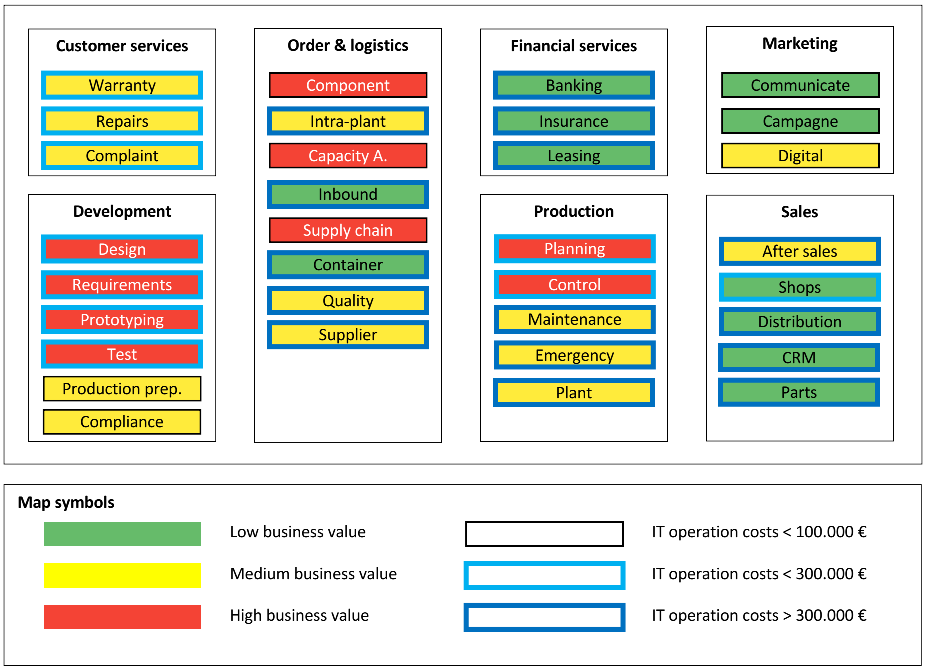

Figure 2.22.: Capability-based heat mapping following Sykes and Clayton [SC12]

- **Freitag et al. [FM11]:** Even if the contribution by Freitag et al. does not deal with capability-based heat maps, it provides a method that can serve as a basis for further visualizations. It reveals how dependencies between business capabilities and elements in an EA can be identified and evaluated. The definition of suitable heat mappings (e.g. color business capabilities red when they have a high number of dependencies to other business capabilities) might help to investigate interfaces between applications as a APC indicator.

Further contributions ([BM05, BB07, PL07, Ha09, Ke09, BM10, Ha13, Fr14] investigate the benefit of BCMs for EAM and APM but do not name dedicated visualizations or focus on how to use the concept for APC.

2.5. Position of thesis in research

Chapter 2 gives an overview of the relevant research fields of this thesis and discusses related work from research and practice. Figure 2.23 illustrates all relevant research fields in an aggregated visualization. The general research field is EAM. As already presented in Figure 2.2, EA can be represented as layered architecture. One layer is the application architecture. APC has recently been discussed both, in science and practice very intensively. This type of complexity reflects the manifestation of APC indicators (more precisely, drivers and their effects). Managing this complexity is the task of APM. Various methods have been introduced to control and reduce the complexity of APs. The analysis of presented APM approaches has shown that an important process step is the creation of transparency. There are currently no dedicated visualizations addressing specific APC indicators.

The concept of BCM receives a lot of attention in the EAM community. It represents a universal visualization tool that can display both technical and business-related information in context. The most promising option is to use heat maps.

The goal of this thesis is to fill the gap of APC transparency in APM by using capability-based visualizations. These visualizations are intended to provide information on the APC status and support practitioners to create suitable actions to tackle specific APC indicators. A publication from our research group has shown that a wide range of stakeholders are interested in APC [AS15]. Depending on the target group, the information demand and therefore the visualizations can vary. The enterprise architect was the most frequently mentioned stakeholder. Therefore, the produced visualizations should primarily focus on the requirements of enterprise architects.

The next Chapter introduces the first iteration to define visualizations for APC management by using BCMs.

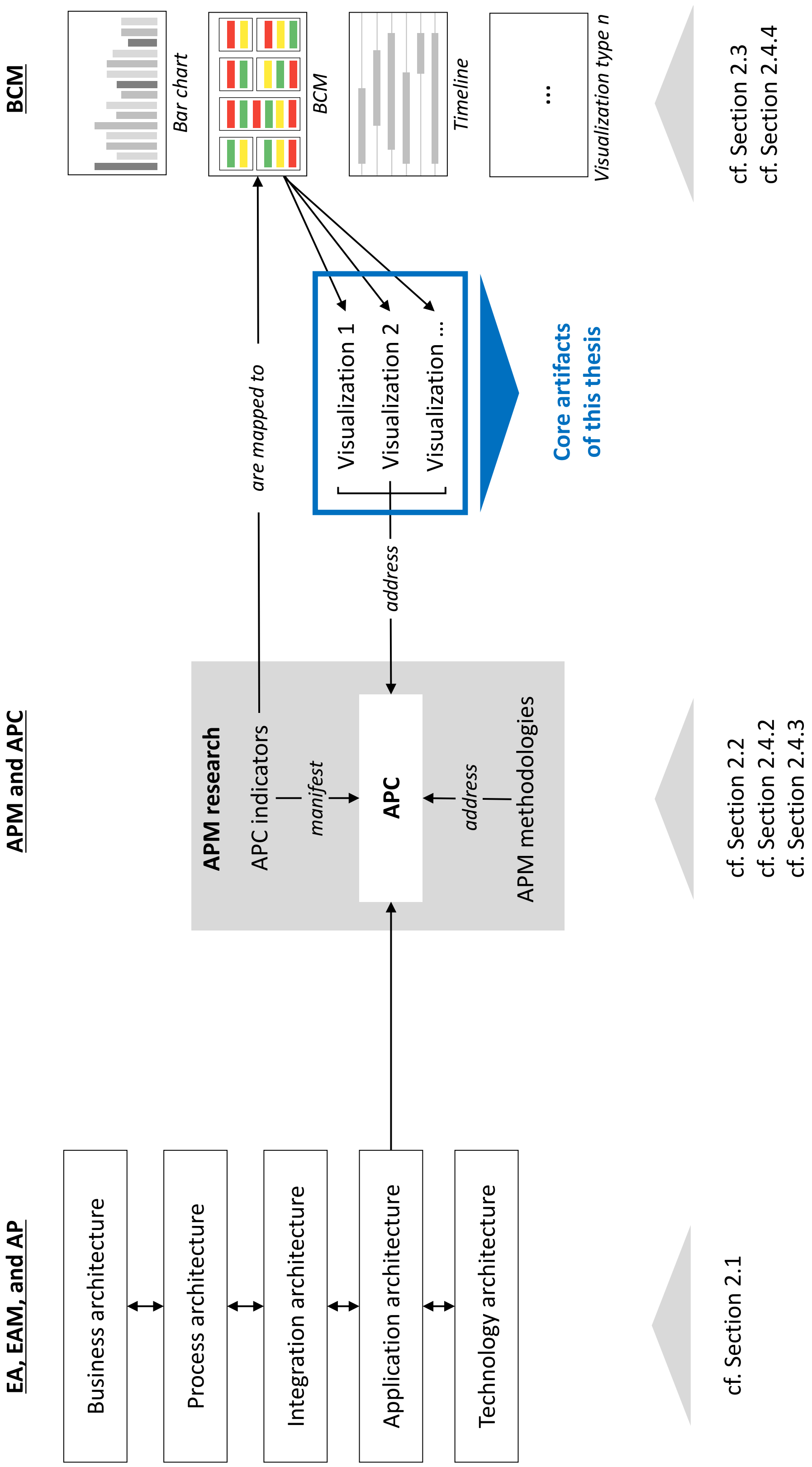

Figure 2.23.: Interaction of relevant research fields of this thesis

CHAPTER 3

Iteration 1: BCM with aggregated APC indicators

This chapter summarizes the research steps and results of the first iteration. Section 3.1 outlines the design of the capability-based visualization concept and explains how the BCM can be used to provide transparency about APC. The developed KPIs to measure APC are described in Section 3.2. The results of the subsequent case study are illustrated in Section 3.3. The chapter ends with a summary of the lessons learned in Section 3.4.

3.1. Design

The fundamental idea is to illustrate APC by adopting three KPIs, each of them reflecting APC from a certain point of view. Each KPI is based on specific APC indicators. The results of the KPIs are visualized on a BCM by using heat maps. As outlined in Figure 1.3, the first iteration is divided into three phases. All phases were carried out in close cooperation with a European automotive company. This ensures that the produced artifacts meet the requirements of practitioners. The company employs approx. 100,000 employees and has an AP with approx. 5,000 applications. All cross-organizational EAM and APM initiatives are planned and steered by a central EA governance department. The design of the KPIs and the visualizations were carried out in cooperation with two EA experts of the company. The KPIs and visualizations were implemented in a software solution as part of a case study and evaluated by conducing interviews with ten EA experts from the same company. The concept of capability-based APC management is illustrated in Figure 3.1.

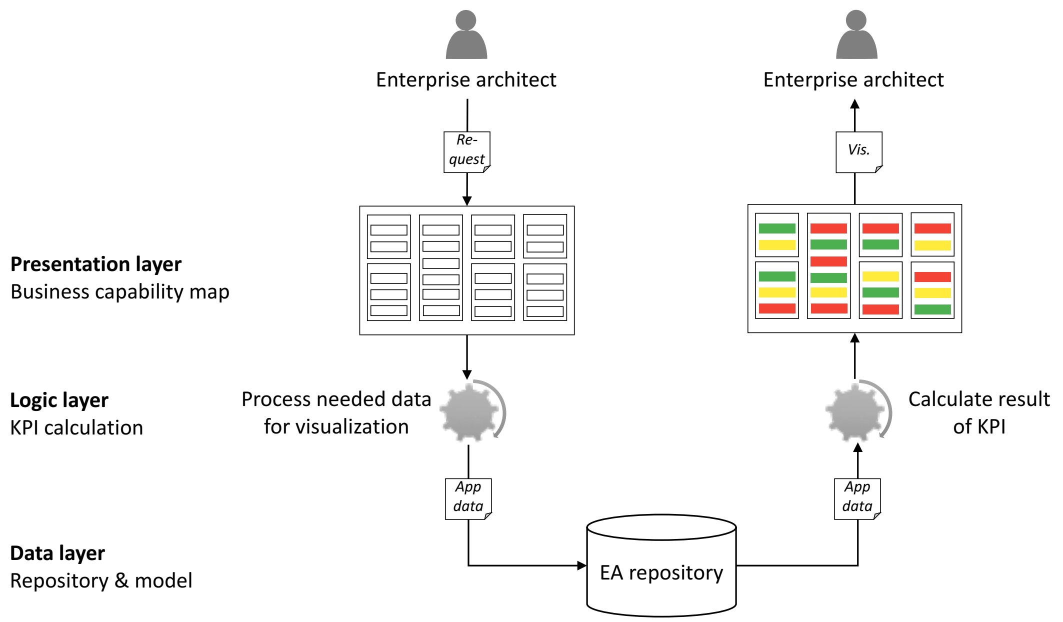

Figure 3.1.: Concept of capability-based APC management

The concept follows three-tier architecture [BH07]. The *presentation layer* illustrates the BCM. The *logic layer* provides the calculated logic for the KPIs. The *data layer* is represented by the EA repository and contains available EA data in raw format. The user, in this case the enterprise architect, initially sees a non-colored BCM. The user has the possibility to select one of the three KPIs. After the enterprise architect has made their selection, the logic layer evaluates which information is needed for the calculation. The query is then passed to the EA repository and returns the requested data back to the logic layer. The respective KPI is then calculated. The results are then visualized on the BCM. More details about the software solutions and their implementation (used data, data model, design, etc.) is illustrated in Section 3.3.

3.2. Development of KPIs

3.2.1. Requirements of KPIs

KPIs are items of *information collected as regular intervals to track the performance of a system* [Fi90] in order to measure the degree to which targets have been achieved. Since Parmenter [Pa15] discusses characteristics, best practices, and success factors of KPIs in an organizational context, this thesis follows the definition:

> **Definition: Key performance Indicator (KPI):**
> *KPIs present a set of measures focusing on those aspects of organizational performance that are the most critical for the current and future success of the organization.*
>
> [Pa15]

In his contribution, Parmenter provides best practices for fruitful KPIs and defines seven characteristics that should be considered during the KPI definition. To ensure the effectiveness of the APC KPIs, these characteristics were considered during the definition.

ID	Characteristic	Description
1	Non-financial	Non-financial measures (not expressed in dollars, yen, pounds, euro, etc.)
2	Timely	Measured frequently (e.g., 24 by 7, daily, or weekly).
3	CEO focus	Acted on by the CEO and senior management team.
4	Simple	All staff understand the measures and what corrective action is required.
5	Team based	Responsibility can be tied down to a team or a cluster of teams who work closely together.
6	Significant impact	Major impact on the organization (e.g., it impacts more than one of the core critical success factors and more than one balanced scorecard perspective).
7	Limited dark side	They encourage appropriate action (e.g. have been tested to ensure they have a positive impact on performance, whereas poor measures can lead to dysfunctional behavior).

Table 3.1.: Characteristic of KPIs [Pa15]

Although one KPI considers operational costs in its definition, the results of all KPIs are values between zero and one. All KPIs consider data that is captured during a defined time period and can be calculated at any time. The KPIs address information needs of enterprise architects and their senior management team (EA governance). All KPIs are evaluated by conducting expert interviews and considering EA measures that are known by all staff members of the EA team. The KPIs illustrate APC from three different viewpoints and can be managed by dedicated teams. The impact of the KPIs is ensured by continuous feedback from the EA experts.

The automotive company added three further requirements for KPI development: they asked for KPIs that are traceable, robust, and comparable. The defined KPIs should be mathematically accurate (robust), understandable for business and IT-stakeholders (traceable), and applicable on an EA level (whole company) or only in single business units or markets. When evaluating APC with the produced KPIs in different business units or markets, the results should follow the same syntax and semantic (comparable).

Parmenter's input provides useful information for quality criteria of KPIs, but does not explain how to develop KPIs. Therefore, the methodology of Jolland et al. was considered for the KPI development process [JL03]. Although KPIs for IS are discussed in various IS standards ([TL07] and publications [Br96, Va96, KK07, Kü11, MM14], these standards do not focus on APC indicators nor do they provide a development methodology with an aggregation function. The approach by Jolland et al. provides a generic development process that explains how to develop KPIs with multiple subindices (in this case APC indicators). Their process is divided in to six sequential process steps. Figure 3.2 illustrates the adapted process.

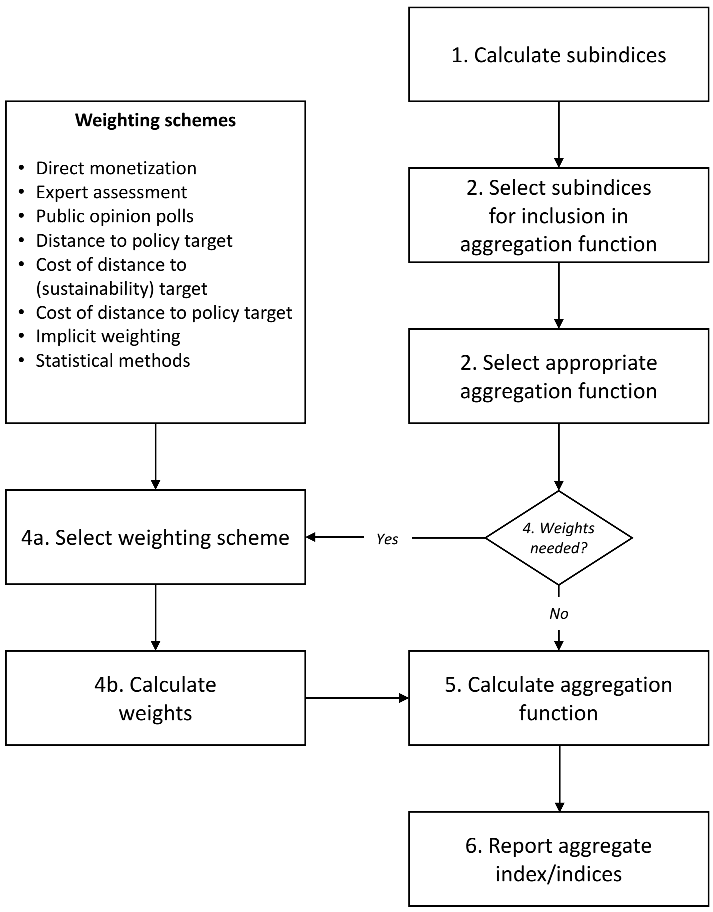

Figure 3.2.: A generic process for calculating aggregate indices [JL03]

1. **Calculate subindices:** First of all the organization should provide an overview of all possible subindices for the KPI definition. In this case, all relevant APC indicators (cf. Table 2.5) and their formats were listed.

2. **Select subindices:** Based on the availability, format, and impact of each APC indicator, relevant data is selected for the KPI definition. Moreover, Jolland et al. outline that the selected subindices should share the same interest (in this case act as an APC indicator), not correlate, to avoid multicollinearity, and find a balance between statistical integrity and their relevance. This means if two indicators correlate and both dates represent significant APC indicators, the organization should evaluate to consider one of two or even both subindices in their calculation.

3. **Select aggregation function:** Although, research outlines plenty of aggregation functions [Ot78, GM09, GM11], they can be grouped into summation, multiplication, averages, maximum, or minimum operations. Yilmaz [Yi17] summarizes that the selection of a suitable aggregation function should consider the following hurdles: format of subindices (increasing or decreasing orientation) and the overestimation problem of the KPI. The first issue means that high dates of some subindices represent good value (date of go live of an application), whereas in other cases low dates represent good value (e.g. number of interfaces). The second issue means that *the KPI exceeds a critical level without any attribute exceeding it. In other words, the status KPI of the application architecture is "bad" although the underlying application attributes are in a good shape* [Yi17]. These problems should be investigated during the KPI definition. Jolland et al. call attention to the parsimony principles which says *the most appropriate function will be that which is the 'simplest' mathematically* [JL03]. For further information about best practices and advices, we refer to the cited articles. The featured aggregation function is outlined in Section 3.2.2.

4. **Decision for weights:** Jolland et al. say that weights are optional. Figure 3.2 outlines nine possible weighting schemes. The impact of each APC indicator was evaluated by *Expert assessments*: each EA expert assigned weights by scattering ten points among all APC indicators. The final weights of each indicator were defined by summing up all points and normalizing them to add up to one.

5. **Calculate aggregation function:** Considering weights within the calculation.

6. **Report aggregated index/indices:** The KPIs were calculated and reported by using real data from the automotive company and discussing the results of the KPIs with ten EA experts (cf. Section 3.3).

The best practices and requirements were aggregated in a checklist, which were adopted during the KPI development process. The checklist is illustrated in Table 3.2.

Description	**Status**
Selected attributes share the same interest.	Yes/No
Selected attributes are not correlated.	Yes/No
Not too many attributes involved in the function.	Yes/No
In-/decreasing scales were tested.	Yes/No
Selected Attributes were tested for over-/underestimation.	Yes/No
The KPI is easily comprehensible.	Yes/No
The KPI can be disaggregated.	Yes/No
The KPI meets requirements of Table 3.3.	Yes/No

Table 3.2.: Checklist for KPI development [AB17]

3.2.2. Identified KPIs

Table 2.5 shows a list of APC indicators that can be used for the development of KPIs. All indicators were evaluated in group discussions with two experts of the automotive company to reveal their applicability and feasibility in their context. Functional overlap and coverage were removed due to missing data. The EA experts suggested removing the application size and documentation indicators, since both are too technical and the EA experts did not see any benefit in using them. Furthermore, they suggested considering an indicator that reveals applications with high business impact: they explained that they were operating various applications that have a significant impact on their daily business (higher than others) in case of an outage. This is why business-critical applications are characterized by an individual indicator, named strategic relevance. A more granular distinguishing (e.g. critical, high, medium, or low relevance) harbours many sources of error due to subjective misjudgments. Thus, the indicators were considered as a binary variable. Table 3.3 gives an overview of the used attributes for each KPI.

Architectural structure	**Quality**	**Impact**
Number of interfaces	Application failure	Operating costs
Capability coverage	Number of incidents	Number of users
Application age	Incident processing time	Business impact
Technology diversity		Strategic relevance
Deviation from standard		

Table 3.3.: Overview of characteristics per KPI [AB17]

Table 3.4 explains the used notations within the equation. The purpose of each KPI and the used weights are explained in the following sections. The company operates in several countries, also called *market*. Although the BCM sets a group-wide business framework, the adopted AP might differ between the markets. This is why the KPIs calculate the APC of a certain market.

Notation	Meaning
C	Set of all capabilities
$c \in C$	Single capability
M	Set of all markets
$m \in M$	Single market
$A_{c,m}$	Set of all applications within the capability $c \in C$ of market $m \in M$
$a \in A_{c,m}$	Single application
K	Set of all incident priorities (low, medium, high, critical)
$k \in K$	Single incident priority
t	Used to denote time periods
$g_{???}$	Weight factors for aggregation

Table 3.4.: Overview of notation in the KPI definition [AB17]

3.2.2.1. Architectural structure

The first KPI evaluates APC from a structural point of view. APC indicators that do not focus on structural deficits but on effects such as costs, incident tickets or downtimes are considered. The KPI calculation is illustrated in equation (3.1).

$$\begin{aligned}
&Architectural\ structure_{c,m} = \\
&\frac{1}{|A_{c,m}|}\sum_{a \in A_{c,m}}(g_{cap}\frac{nCoveredCapabilities_a}{nTotalCapabilities_m} \\
&+ g_{int}\frac{0.5 * nInterfaces_a + nExtInterfaces_a}{nTotalInterfaces_m} \\
&+ g_{age}\frac{age_a}{\max_{m \in M} age_{a,m})} \\
&+ g_{tec}\frac{nTechComponents_a}{nTotalTechComponents_m} \\
&+ g_{std}(1 - \frac{nStandardComponents_a}{nTechComponents_a}))
\end{aligned} \tag{3.1}$$

The equation calculates the architectural structure of an AP for a capability (c) in a market (m). The indicators were aggregated according to the arithmetic mean, rather than the geometric or harmonic mean, as this approach is more intuitive [KA04, RG07, SS08]. The KPI considers five APC indicators: the capability coverage is considered by dividing the number of supported capabilities ($nCoveredCapabilities_a$) of an application (a) by the number of all used capabilities

($nTotalCapabilities_m$) in the market. The number of interfaces is considered by comparing the number of all interfaces of the application with the total number of interfaces in the market ($nTotalInterfaces_m$). Interfaces to applications outside the market ($nExtInterfaces_a$) are rated twice as much as interfaces to applications in the same market ($nInterfaces_a$). The age of the application (age_a) is divided by the oldest application in the market ($\max_{m \in M} age_{a,m}$). Standard deviation of components is considered by dividing the number of standard conform components ($nStandardComponents$) by all used components ($nTechComponents_a$). Since the equation considers the opposite of this ratio, the relative number is subtracted from one. The adopted weights for the APC indicators are illustrated in Table 3.5.

Symbol	**Characteristic**	**Weight**
g_{cap}	Capability coverage	0.47
g_{int}	Number of interfaces	0.3
g_{age}	Application age	0.03
g_{tec}	Technology diversity	0.1
g_{std}	Deviation from standard	0.1

Table 3.5.: Overview of weights for architectural structure [AB17]

3.2.2.2. Quality

The Quality KPI investigates the availability and robustness of the AP of a capability (c) in a market (m) in a specified timeframe (t). It adopts two APC indicators: the downtime of an application ($downtime_a, t$), and the avg. resolution time ($avg.Time_a, k, t$) of all incident tickets ($nIncidents_a, k, t$) in the timeframe (multiplication of number of incidents and avg. resolution time). The KPI calculation is illustrated in equation (3.2).

$$
\begin{aligned}
&Quality_{c,m,t} = \\
&\frac{1}{|A_{c,m}|} \sum_{a \in A_{c,m}} (g_{dow} * downtime_{a,t} \\
&+ g_{inc}(\sum_{k \in K} nIncidents_{a,k,t} * avg.Time_{a,k,t} * P_k))
\end{aligned} \tag{3.2}
$$

The downtime and the avg. resolution time are measured in minutes. The KPI evaluates the criticality of incidents by using a penalty factor (P_k): incidents with a low impact ($incident_{low}$) are rated with 0.1; medium rated incidents with 0.2 ($incident_{medium}$), etc. The penalty definition is illustrated in equation (3.3). The adopted weights for the APC indicators are illustrated in Table 3.6.

$$P = \begin{cases} 0,1 & \text{if } k \in incident_{low} \\ 0,2 & \text{if } k \in incident_{medium} \\ 0,5 & \text{if } k \in incident_{high} \\ 1 & \text{if } k \in incident_{critical} \end{cases} \tag{3.3}$$

Symbol	**Characteristic**	**Weight**
g_{dow}	Application downtime	0.53
g_{inc}	Number and avg. resolution time of incidents	0.47

Table 3.6.: Overview of weights for Quality KPI [AB17]

3.2.2.3. Impact

The Impact KPI reveals the impact of AP failure's, or parts thereof, on the operating business of a capability (c) in a market (m) in a specified timeframe (t). The KPI adopts four APC indicators: the operating costs ($opCost_a, t$), the number of productive users ($nUser_a, t$), the business impact ($businessImpact_a$), and the strategic relevance ($strategicRelevance_a$) of the application. The KPI is illustrated in equation 3.4.

$$\begin{aligned} & Impact_{c,m,t} = \\ & \frac{1}{|A_{c,m}|} \sum_{a \in A_{c,m}} (g_{cst} \frac{opCost_{a,t}}{\max_{m \in M} opCosts_{m,t}} \\ & + g_{usr} \frac{nUser_{a,t}}{nEmployees_{m,t}} \\ & + g_{bus} businessImpact_a \\ & + g_{str} strategicRelevance_a) \end{aligned} \tag{3.4}$$

Although operating costs are paid anyway, regardless of whether the application is running properly or not, the EA experts mentioned that this indicator plays a significant role in their impact calculation: the higher the operating costs of an application, the more resources are lost in the case of failure. Since the KPI should not consider monetary values, the operating costs are considered by dividing the operation costs of every application ($opCost_a, t$) by the application with the highest operating costs ($\max_{m \in M} opCosts_{m,t}$). The more users utilize an application, the more employees are affected by an application failure. The number of users is considered with a normalized value by dividing the number of productive users for an application ($nUser_a, t$) by the number of all employees that are working in the market ($nEmployees_m, t$). Although the business impact of an application can be quantified with a business impact analysis (monetary value that explains how high the loss for the organization is when a certain application fails), the automotive company suggests using a binary variable:

applications with a high business impact are rated with one; applications with medium or low business impact are rated with zero. Applications that do not lead to monetary losses for the organization, but require extra attention – such as application for marketing or board purposes – are labeled with the ($strategicRelevance_a$) indicator. They are also considered with a binary value (one= high strategic relevance; zero= low or medium strategic relevance). The adopted weights for the APC indicators are illustrated in Table 3.16.

Symbol	**Characteristic**	**Weight**
g_{cst}	Operating costs	0.33
g_{usr}	Number of users	0.1
g_{bus}	Business impact	0.3
g_{str}	Strategic relevance	0.27

Table 3.7.: Overview of weights for the Impact KPI [AB17]

3.3. Case study

This section explains the case study carried out with the automotive company. The study can be divided into three phases: (1) identifying a suitable dataset and calculating the KPIs (cf. Section 3.3.1), (2) implementing a software solution that illustrates the results of the KPIs on a BCM (cf. Section 3.3.2), and (3) evaluating the results (cf. Section 3.3.3). The case study considers the recommendations by Yin [Yi13]. Since the case study aims to evaluate a new approach for creating transparency about APC, rather than increasing the richness of a theory, it has been decided to only conduct a single case study. The type of case study is exploratory (continuous optimization of software solutions during implementation, semi-structured questions in evaluation interviews). All results of the case study were documented in a protocol and communicated to all participants. Section 3.4 gives an overview of the key findings and lessons learned.

3.3.1. Collect data and KPI calculation

As previously outlined, the automotive company uses approx. 5,000 applications in several markets. The number of applications only considers executable software with source code (no Microsoft Excel[1] sheets with macros). Based on the defined KPIs, six potential markets and their APs were analyzed regarding their feasibility to evaluate the KPIs. After reviewing the data repositories, it became clear that the raw data had to be transformed into a suitable format and this particular undertaking would take some time. Since the goal of the case study was to evaluate if the principle works at all, it was decided to focus on data from one small market. The selected market operates in southern Europe with approx. 100 employees and 26 applications

[1]Spreadsheet software by Microsoft Corporation

providing mainly financial services. Their operations are supported by seven L0 and 12 L1 business capabilities. Although most of the the dataset was stored in one EA repository, some data, such as incident tickets, was stored in separate repositories. The data extraction and cleansing took several months. A more comprehensive description of the data extraction and cleansing process is documented in Yilmaz's study [Yi17]

In line with Jolland et al. [JL03], all APC indicators within a KPI were tested for correlation in order to avoid multicollinearity. The test was conducted with the statistic software R^2. Although the number of interfaces correlates with the number of technology components and the number of high incidents with the number of critical incidents, the dataset of 26 applications is too small to derive a statistical significance. The results of the statistical tests are illustrated in Appendix A1. Based on the results of the calculations and discussions with the EA experts, three thresholds were defined for poor, medium, and good results. The thresholds are illustrated in Table 3.8.

KPI	**Thresholds**		
	Good	Medium	Poor
Architectural structure	0 – 0.11	0.12 – 0.21	>0.21
Quality	0 – 201	202 – 501	>501
Impact	0 – 0.11	0.12 – 0.31	>0.31

Table 3.8.: Thresholds for KPIs [AB17]

Table 3.9 shows the results of the Architectural complexity KPI calculations. Due to a confidentiality agreement, the original names of business capabilities may not be displayed. The numeric naming follows the following syntax: first digit= ID of the L0 business capability; second digit= ID of an associated L1 business capability. The calculations always refer to the architectural structure of the L1 business capability. The second row shows how many applications support the respective L1 business capability and were therefore considered in the calculation.

BC:	1.1	2.1	2.2	2.3	3.1	3.2	4.1	5.1	6.1	7.1	7.2	7.3
Amount:	2	5	1	1	10	2	7	1	3	1	1	1
Result:	0.05	0.12	0.18	0.28	0.10	0.04	0.12	0.28	0.06	0.28	0.28	0.10

Table 3.9.: Results of Architectural structure KPI calculations

In total, four business capabilities have a poor, three a medium, and five a good architectural structure. A closer look into the dataset reveals that one certain application supports all four business capabilities while having a poor architectural structure. It turned out that the respective application supports eight different business capabilities throughout the organization with a high number of interfaces. Seven technological components are used to operate the application. The age of the application is acceptable. However, the poor condition of the application affects the

[2] Software for statistical computing and graphics by R Core Team

overall condition of the business capability. A larger dataset would decrease the effect of single applications.

The results of the Quality KPI are illustrated in Table 3.10. Two business capabilities have a poor, seven a medium, and two a good condition. The poor condition of the two business capabilities occured due to the fact that the supportive applications had a high number of incident tickets or a long avg. time for solving.

BC:	1.1	2.1	2.2	2.3	3.1	3.2	4.1	5.1	6.1	7.1	7.2	7.3
Amount:	2	5	1	1	10	2	7	1	3	1	1	1
Result:	168	296	125	252	494	1053	599	252	323	252	252	208

Table 3.10.: Results of Quality KPI calculations

The results of the Impact KPI are illustrated in Table 3.11. Four business capabilities have a poor, three a medium, and five a good state.

BC:	1.1	2.1	2.2	2.3	3.1	3.2	4.1	5.1	6.1	7.1	7.2	7.3
Amount:	2	5	1	1	10	2	7	1	3	1	1	1
Result:	0.02	0.31	0.01	0.32	0.11	0.04	0.11	0.32	0.20	0.32	0.32	0.01

Table 3.11.: Results of Impact KPI calculations

3.3.2. Tool implementation

The following section describes the implemented software solution. It explains how the conceptual design of the software was defined, what requirements were determined for the implementation and what the implemented solution looks like.

3.3.2.1. Conceptual design

In general, there are various possibilities to create visualizations in the EAM environment. In a recent study by Roth et al. [RZ14], existing EAM repository vendors have been investigated regarding their visualization possibilities. The study reveals that current solutions on the market provide capability-based visualizations and the automotive company uses a market-leading EAM tool that also provides such visualizations. However, it was decided to implement the visualization of the KPIs with a new software solution: the current EAM tool requires in-depth knowledge about its functionality and the implementation of the desired visualizations would take long time. Chi and Riedl [CR98] define a framework that describes how visualization systems can be derived from existing information sources. The implemented software solution can be considered as such a system, since it provides different visualizations interactively on a user interface. The adapted *pipeline* [CR98] for this case study is illustrated in Figure 3.4

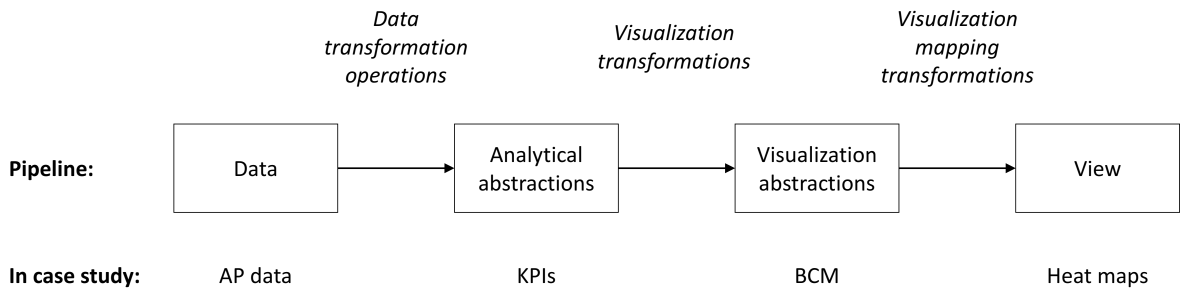

Figure 3.3.: The information visualization pipeline (based on [CR98])

Raw *Data* serves as a starting point and is processed through *Data transformation operations* in to appropriate *Analytical abstractions*. In this case, the AP data illustrates the raw data, the defined equations, the data transformation operations, and the KPIs the are represented by the analytical abstractions. The results of the KPIs are brought to *Visualization abstractions* by *Visualization transformations*. Table 3.8 introduced thresholds for KPI results, which are used for heat mapping definitions. The visualization abstraction is the BCM, which provides the heat mapping possibilities. The dedicated *View*, in this case the heat mapping of each KPI calculation, is performed by *Visualization mapping transformations* (poor= red; medium= yellow; good= green). The analytical abstraction step is already explained in Section 3.3.1. Coming up, it is explained how the results are visualized on a BCM within a software solution. Based on the introduced pipeline of Chi and Riedl [CR98] and the defined KPIs, the concept for a capability-based APC management (cf. Figure 3.1) were concertized. Figure 5 illustrates the updated concept.

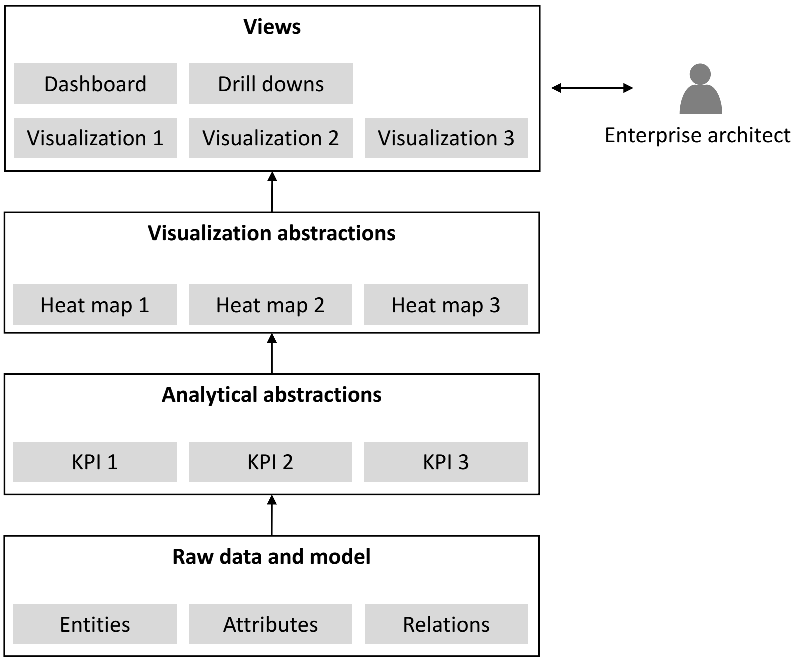

Figure 3.4.: Capability-based APC management concept using KPIs (based on [CR98, Re17])

The refined concept considers four layers: the original AP data and its corresponding data model are managed in the *Raw data and model* layer. Even research shows that EA information is documented across several data sources and information is collected manually in practice [HM12, FB13, RH13], standardized documentation in one EA repository is desirable. This enables the maintenance of a data model in the same system without external data delivery. The *Analytical abstractions* layer contains the equation for the KPIs. The required data is imported from the EA repository. The *Visualization abstractions* layer transforms the results of the KPIs to visualization rules. In this case it defines what kind of heat mapping should be generated from the KPI results. The final visualizations are illustrated in the *Views* layer. It also contains the implemented operational options (cf. Table 3.12 and 3.13 for functional- and non-functional requirements) and is the single interaction point for the *Enterprise architect*.

Research provides much more detailed concepts for such a view: Reschenhofer [Re17] and Roth [Ro14] amongst others [KB10, TS13, RR14] name dedicated experts and responsibilities (e.g. analytics professionals, data modeling experts, view-template developers) and differentiate between separate models for each layer. Schaub et al. [SM12] explain that an overarching model *has to try to capture the entirety of all relevant entities across all business domains and industry sectors* and that such an approach is *doomed to fail* [SM12]. In their research they differentiate between almost 18 models for an EA visualization pipeline (e.g. data, data interaction, view interaction models). A definition of separate models including the modeling best practices and the identification of responsibilities per layer are the foundation of a proper software solution for EA visualizations. Even though these granular elaborations are not considered and are a clear limitation of this concept, they were deliberately not considered for the following reasons:

1. The tool serves to evaluate, whether the produced visualizations and the implemented interaction possibilities provide advanced transparency about APC. An implemented solution gives a better understanding of what an actual visualization can look like compared to a painted graphic. A prototype solution is sufficient for this purpose.
2. Discussions with the EA experts revealed that a concept, as suggested in the literature, is out of touch with their practices. They defined and maintained one EA model in their EA repository. Views and interaction possibilities are either predefined by the EA repository or programmed directly by solution architects.
3. The automotive company employs a certain number of solution architects for their EA repository, which are almost responsible for all layer activities. If an enterprise architect or another stakeholder asks for specific report or KPI, the corresponding requirements are communicated to the solution architects of the EA repository. These perform all necessary implementation activities. There is no distinction between responsibilities per layer.

The equations, heat mapping rules, and visualizations have been defined in the source code of the software. The AP data is stored in a separate file (Microsoft Excel file). The software imports the information for the calculations from this file. A data model has been defined to keep track of dependencies between the AP data. The data model is illustrated in Figure 3.5. The data model takes five classes into account. The classes *Business capability*, *Application*, and *Incidents* provide all the information needed to calculate the KPIs and to create the visualizations. The *Service* class is used for the following reason: incident tickets are not issued directly for applications. They are created for services which are supported by applications. An indirect mapping (incident is opened for service A and service A is supported by application B), allows the mapping of incidents to applications. The problem is that services can be supported by multiple applications. In this case, the description of the incident ticket was analyzed to identify the affected application. If this was not possible, the issued tickets for a certain service were distributed to all applications that support the service. This reduces the quality of the data, but is not critical for this case: a multiple mapping of applications to the same service is rare and the data quality is high enough to calculate the KPIs correctly and evaluate the benefit of the visualizations. The model is limited to the most necessary information and reflects the reality of the case study partner [St73]. Further information about applications, business capabilities, and the other entities are not considered in the model.

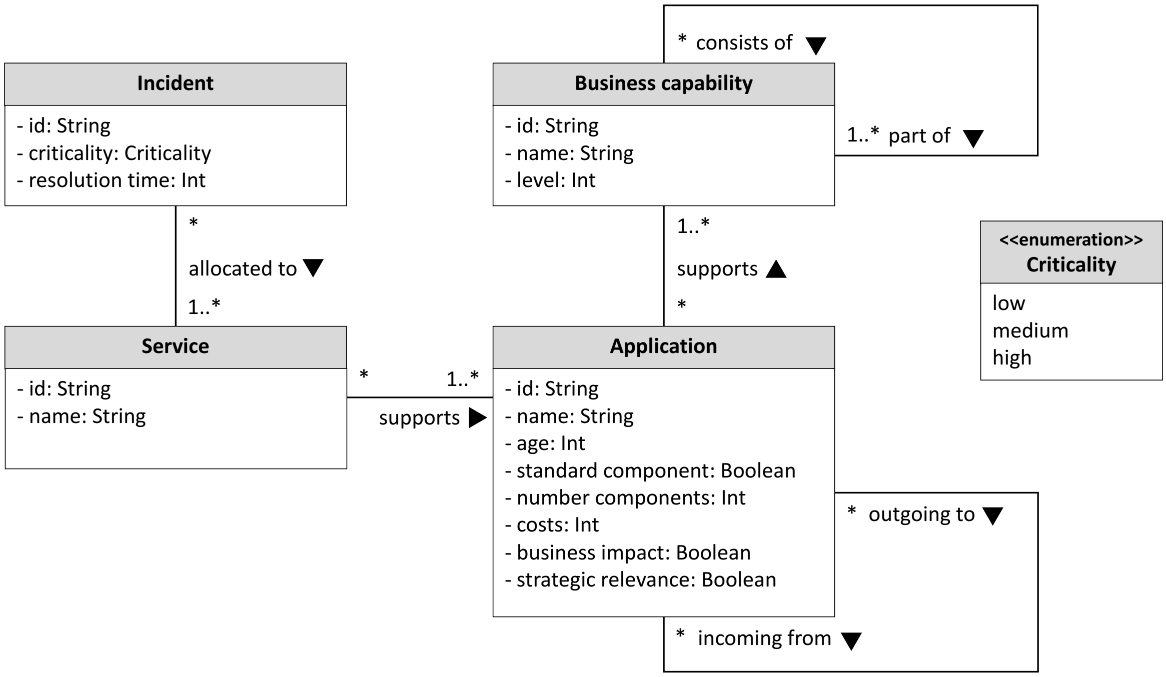

Figure 3.5.: Data model for capability-based APC management using KPIs (based on [Yi17])

3.3.2.2. Identified requirements

Prior to the implementation of the software solution, functional and non-functional requirements for the software solution were determined. These were derived from group discussions with the automotive company. The documentation of the requirements aligns to the template of Robertson and Robertson [RR00]. These distinguish between different types of requirements and specify description and fit criterion for each requirement. The identified requirements are illustrated in Table 3.12 and 3.13. 13 functional and seven non-functional requirements were identified. The requirements analysis distinguishes between the following requirement types:

- **Interaction:** Describes how the user interacts with the system, which setting options the user has and ensures that unnecessary usage barriers are avoided (e.g. open drill-down, Microsoft PowerPoint[3] export).
- **Business capability visualizations:** Describes how the visualization of the business capabilities should be implemented.
- **AP visualization:** Describes how application information should be implemented.

The ID of the requirements indicates whether it is a functional (*FREQ*) or non-functional (*N-FREQ*) requirement. Most of the requirements could be fulfilled directly with the implementation. The subsequent evaluation is presented in Section 3.3.3 and examines (1) the quality and significance of the KPIs and (2) the design of the software solution.

[3]Presentation program by Microsoft Corporation

Type	ID	Name	Description	Fit criterion
Interaction	FREQ–1	Microsoft PowerPoint export	Visualizations should be exportable.	Generated visualizations can be exported to a Microsoft PowerPoint .pptx file.
	FREQ–2	Dashboard	The user can adapt visualizations to his information need.	The software provides a dashboard in which the user can select the information to be considered for visualization.
	FREQ–3	Time period	The user is able to to consider a dedicated time period.	The dashboard provides the possibility to select a certain time period.
	FREQ–4	Market	The user is able to consider individual markets.	The software provides the possibility to select a certain market within the dashboard.
	FREQ–5	KPI type	The user can select which KPI should be considered for visualization.	The dashboard provides the possibility to select a KPI.
	FREQ–6	Drill-down	The user wants to identify root causes for business capability assessments in the AP.	The software provides a drill-down function (business capability to applications).
Business capability visualization	FREQ–7	Layout	The user should quickly find his way through the visualization.	The original design of the company's BCM is considered within the visualization.
	FREQ–8	Color coding	The user has to be able to interpret the APC based on color coding	The results of the KPIs are visualized by red (poor), yellow (medium), and green (good).
	FREQ–9	Granularity	The APC status is calculated for level-1 business capabilities.	The visualization reveals the APC status only for level-1 capabilities.
	FREQ-10	Strategic relevance	Strategic relevant business capabilities are highlighted.	Strategic relevant business capabilities are highlighted with a bold boarder.
AP visualization	FREQ-11	Architectural structure	Results of the Architectural structure KPI should be visualized.	The results of the architectural structure is visualized by using heat maps.
	FREQ-12	Quality	Results of the Quality KPI should be visualized.	The results of the architectural structure is visualized by using heat maps.
	FREQ-13	Impact	Results of the Architectural structure KPI should be visualized.	The results of the architectural structure is visualized by using heat maps.

Table 3.12.: Overview of functional requirements (based on [Yi17])

Type	**ID**	**Name**	**Description**	**Fit criterion**
Interaction	NFREQ–1	Visibility of status	The software informs at any time about the current activity.	The software displays about selected parameters.
	NFREQ–2	Real world terms	The user is familiar with the used expressions.	The software uses company-related vocabulary.
	NFREQ–3	Control of freedom	The user can reset any visualization.	The software adopts an exit button on every visualization.
	NFREQ–4	Consistency	Visualizations should be comparable.	The software uses the same template for any type of view.
	NFREQ–5	Error handling	Errors cannot occur due to operating errors.	The user cannot input any manual data and the system does not crash in case of parameter selection.
	NFREQ–6	Ease of use	A user can interact with the software without extensive experience	The landing page provides needed instructions.
	NFREQ–7	Design	The software displays only essential information	Visualizations only display the colored BCM, an overview of the selected items, an explanation for the heat mapping, one button to exit and another for the Microsoft PowerPoint export.

Table 3.13.: Overview of non-functional requirements (based on [Yi17])

Section 3.3.2.3 shows the implemented software, explains its functionalities and clarifies which requirements could be fulfilled directly by implementation. One requirement has to be explained in more detail. The experts of the automotive company asked for a function that enables the identification of AP-related root causes of business capability assessments. Example: if a business capability has poor architectural structure and is colored red, the user should be able to see (1) which supporting applications are responsible for that and (2) which application characteristics (e.g. age) are in poor condition. For this information demand, the software offers a drill-down function on each visualization. Figure 3.6 shows the conceptual design.

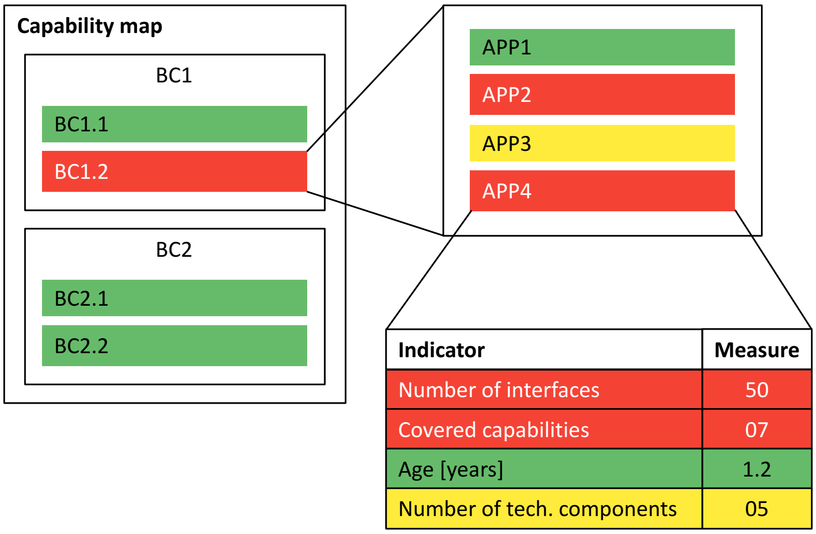

Figure 3.6.: Conceptual design of drill-down opportunity [Yi17]

In this example, business capability BC 1.2 is colored red. When the user clicks on the business capability, a list of all supporting applications and their rating is displayed. When the user clicks on an application, all characteristics of the application are displayed. Seperated to the KPI results, there was also the requirement to define absolute evaluation criteria for application characteristics. For example, if an application has more than 12 interfaces to other applications, the corresponding field is colored red. These absolute evaluation criteria are valid and separated from the results of KPIs. The experts are convinced that certain application characteristics lead to APC regardless of the KPI calculations and should be transparent. The thresholds are defined by the EA experts. Table A.2 shows the thresholds for the application characteristics of the Architectural structure KPI. The thresholds for Quality and Impact KPI are illustrated in the Appendix A2.

Some requirements (*FREQ-7, -8, N-FREQ-6, -7*) aim to guarantee the simplicity and intuitiveness of the visualizations. As outlined by Moody [Mo09], *goals such as "simplicity", "aesthetics", "expressiveness, and "naturalness" are often mentioned in the literature, but these are vaguely defined and highly subjective.* In his research [Mo09], he summarizes a set of principles for designing effective visual notations. Table 3.15 illustrates which guidelines are defined by research and how these were considered in the visualizations design. All design guidelines and further literature on the advice are illustrated in Moody's publication [Mo09].

Application characteristic	Good	Medium	Poor
Number of interfaces	0-5	6-10	>10
Capability coverage	0-2	3-5	>5
Application age	0-3	3.1-6	>6
Technology diversity	0-3	4-6	>7

Table 3.14.: Thresholds for application characteristics, considered in Architectural structure KPI

Design guideline	Consideration in artifact design
Symbol redundancy: Semantic constructs should map to unique graphical symbols *Symbol overload*: Each symbol should have a single meaning	Business capabilities are illustrated with rectangles. L0 business capabilities have a different design (size, font size, color) to L1 business capabilities. Application information is only visualized in the drill-down view and follows a different design in terms of color and font size. A more radical design would use different shapes for different types of information. However, the EA experts mentioned that the use of different shapes would be confusing.
Symbol excess: The integration of boxes or other shapes with no function but explanations might lead to misinterpreted constructs [Mo09].	The footer of the visualizations considers a legend, which explains the used color coding. Other constructs without a semantic meaning are not used in the visualizations.
Redundant coding: The use of multiple variables helps to distinguish between different types of symbols and their meaning.	The color coding increases the expressiveness of the shapes.
Semantically Transparent Relationships: The use of transparent relationships helps to interpret the relationship between constructs.	L1 business capabilities are illustrated as a subset of a specific L0 business capability. Application characteristics are illustrated as a subset or list of applications.
Hierarchy: Hierarchical visual languages support recursive decompositions and supports the understanding of diagrams.	Applications and application information can be accessed with the drill-down view and can be interpreted as a decomposition of the business capabilities.
Introduce symbol deficit: Not all constructs should be visualized graphically, as too much graphic information can be counterproductive.	The exact results of the KPIs are illustrated with numbers and are not visualized.

Table 3.15.: Considered design guidelines

The color coding (red, yellow, green) was defined by the EA experts. Research provides manifold possibilities for information visualization (e.g. [Wa88, Sp01, WG08, WF09, Wa12]), but this domain is too far away from the scope of this thesis. For further information, we refer to the mentioned publications.

3.3.2.3. Implemented software

The software (web application) has been programmed in *AngularJS*[4] and follows the best practices of material design[5]. In line with Few [FE07] the dashboard is designed in a minimalistic way: colours are kept to a minimum and align to the corporate design guidelines of the automotive company (*FREQ–7*). In addition to the selection of parameters, only information about the KPIs (**3**) is displayed (*NFREQ–7*). It is displayed what each KPI should measure and which APC indicators are considered within each KPI. The user can specify three parameters **(1)**: first drop-down-menu: year; second: market, and third: KPI (*FREQ–2, 3, 4, 5, NFREQ–5*). This case study relies on data for one market and one time frame (year 2016). Consequently, only one record could be selected for the year and the market drop-down. All three drop-down menus are mandatory. If not all three drop-down menus are selected, the evaluation cannot be started (error message when visualization should be started). To start the analysis and visualize the results on the BCM, the user must press the *Generate Map* button (**2**).

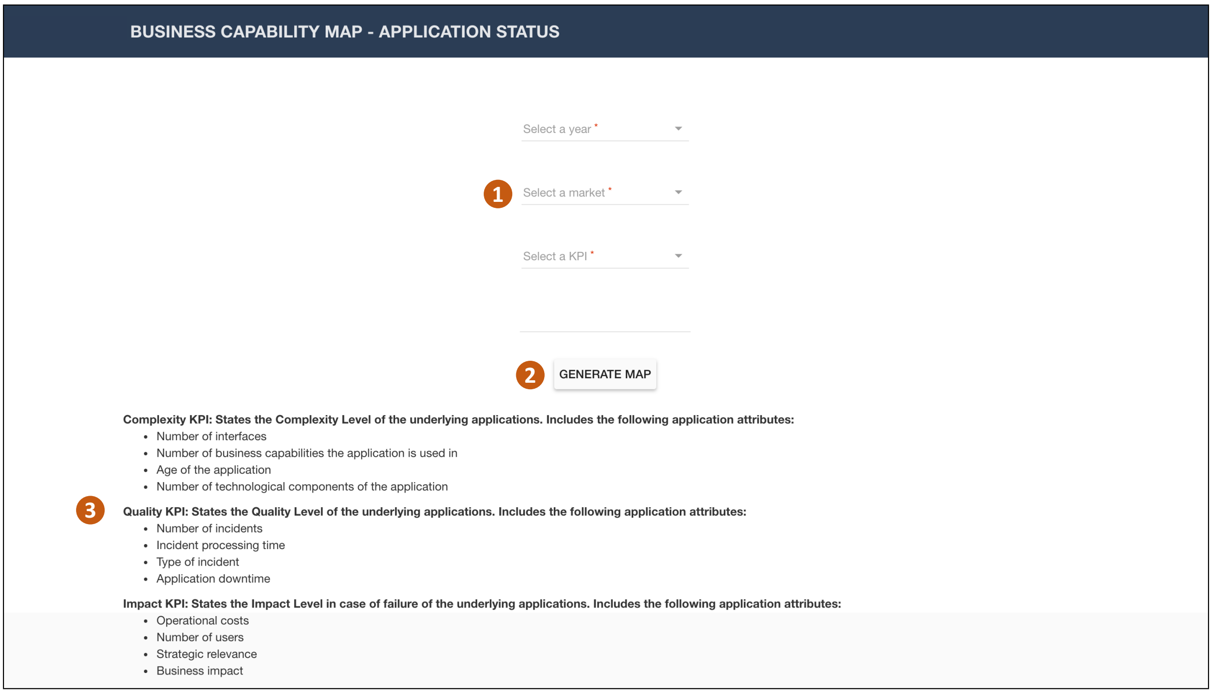

Figure 3.7.: Starting dashboard (based on [Yi17])

After starting the analysis, the result is displayed in a new window on the BCM. Figure 3.8 shows, what such a visualization looks like. The example shows the results of the Architectural structure KPI calculation. Due to a confidentiality agreement, the real names of the business capabilities and applications are not displayed. As specified in the requirements analysis, only L1 business capabilities are colored (FREQ–9). If no data is available, the business capability retains its original color. From this it can be derived which business capabilities support the selected market (assumption: a business capability is always supported by applications). The

[4]Java script based open source web application framework programming language by Google Inc.
[5]Design language by Google Inc.

selected parameters are displayed at the top of the map **(1)** (*NFREQ–1*). The button in the upper left corner resets the visualization and returns the user to the dashboard **(2)** (*NFREQ–3*). The button in the upper-right corner can be used to download the colored BCM into a Microsoft PowerPoint file (screenshot) **(3)** (*FREQ–1*). The legend in the bottom corner of the visualization explains the color coding (*FREQ–8*). The ranges fit to the selected thresholds of the KPIs (see Table 3.8 in Section 3.3.1). The experts wanted the BCM to always emphasize strategically important business capabilities, regardless of the selected KPI and its results. Strategically relevant business capabilities are marked with a red border (*FREQ–10*).

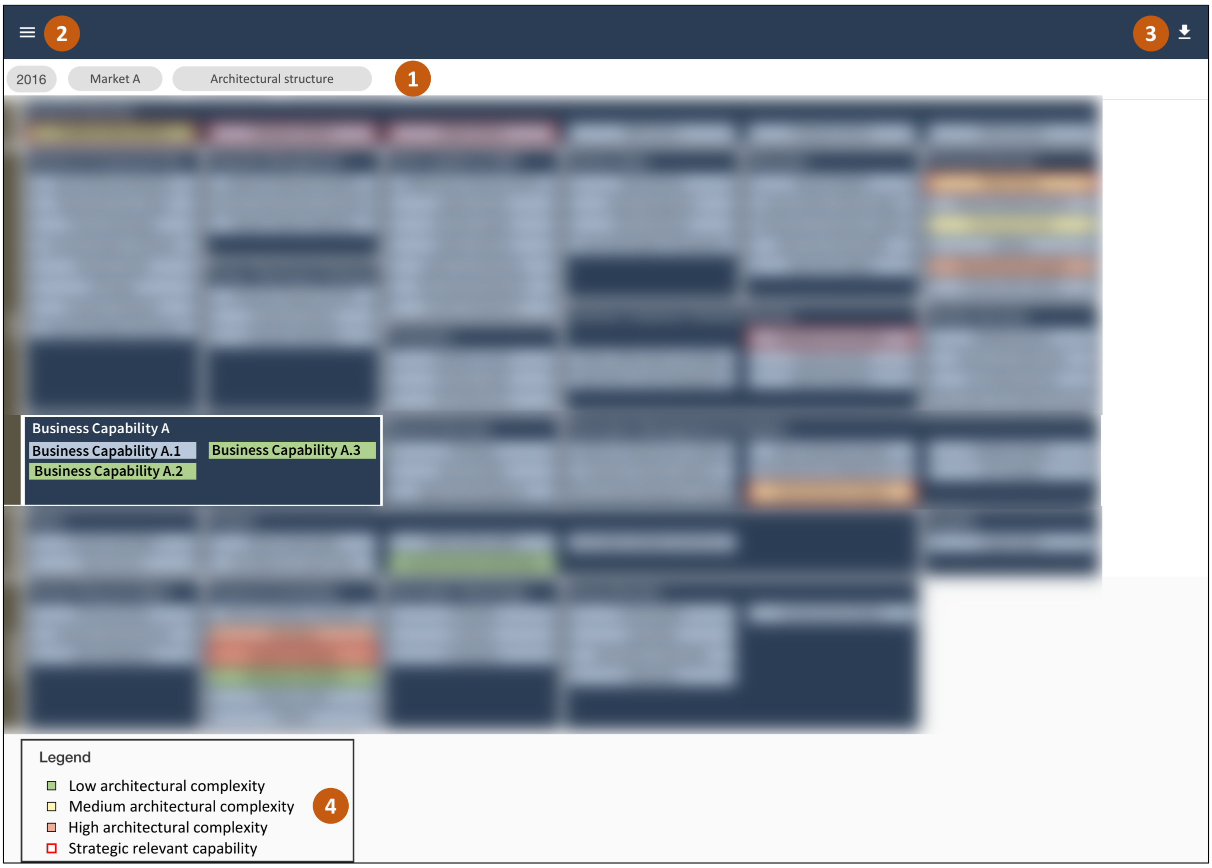

Figure 3.8.: Capability-based heat map with the Architectural structure KPI (based on [Yi17])

The user can click on a business capability to open the drill-down view (*FREQ–6*). Example: business capability A.3 is colored yellow. When the user clicks on the business capability, the visualization shows, in an embedded window, which applications support the business capability and which results have been calculated for each application. By a further click on the application, the user sees all characteristics of the application. In the example, business capability A.1 is supported by five applications. Next to each application, the calculated value of the KPI is documented. The first four applications are all under the threshold of 0.1 and are colored green. Application five is above the threshold of 0.21 and is colored red. The user can display the characteristics of an application by clicking on it. In this example, the number of supported business capabilities and interfaces are high and colored red. If a characteristic is not colored, there was no information available and the characteristic is not considered in the KPI calculation. The results of all three KPIs are visualized according to this scheme *NFREQ–4*. The Microsoft PowerPoint export function is only available for the BCM view. When the user clicks on the button, the Microsoft PowerPoint file containing a screenshot of the colored BCM is automatically downloaded. Drill-down views cannot be downloaded.

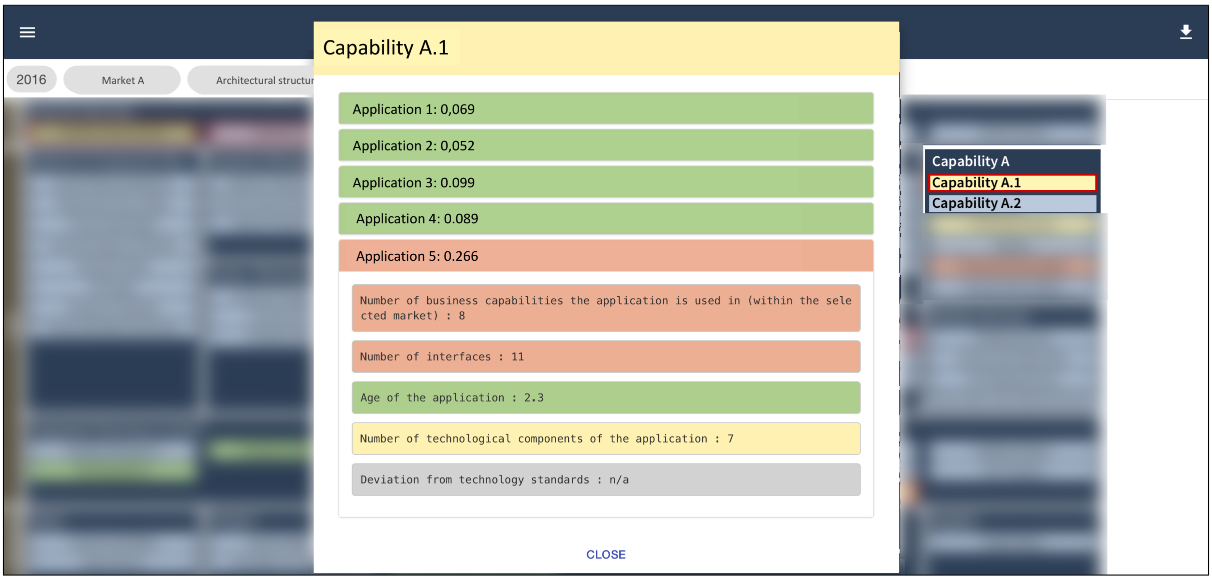

Figure 3.9.: Drill-down into one business capability (based on [Yi17])

3.3.3. Evaluation

Many requirements could already be fulfilled with implementation. The evaluation does not aim to examine each function of the tool but to investigate the idea of (1) evaluating APC indicators with KPIs, (2) visualizing the APC status by capability-based heat mappings, and (3) whether such a software-driven solution helps to increase transparency.

In general, there are three different approaches on how to attempt an expert interview [Ma02, MN07]: on the one hand, the interview could be very structured with a pre-defined sequence of questions. On the other hand, the interview could be unstructured and give the respondents a high degree of freedom to tell stories on a given topic. The third option is to conduct group discussions in which two or more experts are interviewed at the same time. There were no empirical values for the developed KPIs, the visualizations, or the software solution and it was unclear which part of the developed artifacts should be discussed in more depth and which not. Therefore, the evaluation was carried out through semi-structured interviews. A well known technique is the narrative interview: the interviews start with a storytelling impulse from the interviewer, then the interviewees speak freely and without restriction [BW94, Wi86, Ma02]. The interviews were divided up as follows: in the first part of the interview the study was explained. In the second part, the KPIs, visualizations, and software were presented. The presentation was conducted semi-structured and questions and suggestions of the participants were discussed directly during the presentation. In the third part, the respondents were asked to complete a questionnaire, which is divided into three parts: general questions about the person and the company, questions about the software and visualizations and questions about the KPIs. The questionnaire contained mainly likert-scale-based questions, but offered the possibility to add suggestions or comments. The questionnaire is presented in the Appendix A3. Each interview lasted approx. 30 minutes. Each interview was conducted personally.

Participant	**Position**	**Experience (years)**
#1	Enterprise architect	35
#2	Enterprise architect	8
#3	Enterprise architect	9
#4	Enterprise architect	17
#5	Enterprise architect	22
#6	Enterprise architect	15
#7	IT demand manager	7
#8	IT provider manager	10
#9	Governance specialist	4.5
#10	IT specialist	11

Table 3.16.: Overview interviewed experts [AB17]

Since the software and the application data include company-related information, only employees of the automotive company were interviewed. I made sure to only interview employees that are familiar with the BCM concept and are affected by APC in their daily work. 60% of the attendees are enterprise architects and the other 40% are involved in EA related projects. The participants have approx. 14 years of experience in EAM. All participants stated that EAM is mainly oriented towards TOGAF in their company and the maturity is quite high: standards and methodologies are defined in detail and all relevant stakeholders are familiar with the relevant documents. When the interviews steered towards APC and BCM, it quickly became clear that all participants were aware of the problem and had a clear picture on the subject.

After a short introduction, the dashboard was shown to the participants. The individual drop-down menus and the KPIs were presented. At this point, the structure of the KPIs had not yet been discussed, but it had been explained which KPIs have been defined, which output can be expected and which APC indicators are considered in each KPI. After the first interviews it became clear that there was already a need for discussion at this time and the participants wanted to know to what extent the APC indicators are considered and in which format the APC indicators are available. There was also a need for more information on the KPIs: the experts wanted to know what exactly is being examined by the KPIs and what consequences can be derived from the results. Three questions from the questionnaire refer to discussions and impressions of this interview phase. It was discussed whether a KPI for the respective view (architectural structure, quality, impact) provides added value in APC management. The results are summarized in Figure 3.10. The Architectural structure KPI was considered to be the most valuable. No participant had considered the KPI to be unimportant and the desired core statement was clear. 80% agreed that a respective KPI would support their APC management activities. Two participants were more cautious: they had doubts whether the considered APC indicators are capable of measuring the maturity of an architectural structure and whether a KPI could help to identify weaknesses.

The participants assessed the Quality KPI with more skepticism. 50% were not sure whether this KPI is important or not: in particular, they saw the problem in defining the term *Quality* and pointed out that it is difficult to determine exactly what needs to be done on the basis of a corresponding result from the KPI. They considered the selected APC indicators to be important and shared the opinion that they are closely interlocked, but outlined that the quality of an AP depends on significantly more factors (e.g. fulfillment of business requirements, effectiveness of the technologies used, etc.). The third KPI showed a clearer picture: 50% of the participants considered a KPI to measure the affect of AP failures within business capabilities as important. The APC indicators taken into account are crucial to determine the impact of failures of an AP on the operating business. 30% did not agree with the KPI: there are e.g. applications that only have a few productive users but are essential for the business (e.g. accounting applications) and said that quantifying the business impact and the strategic relevance in one binary ratio is too vague.

The feedback from the introductory course creates a first impression of the defined KPIs, but all participants stated that they only shared their first opinions. The visualization of the KPIs on a BCM is more crucial. In the next step, all three KPIs were calculated on the basis of the available data set and were visualized on the BCM. The BCM view, drill-down function, and the Microsoft PowerPoint export were presented and explained to all users. During the presentation, great importance was attached to explaining the connection between the business capability colors and the actual KPI values. The users were shown how a red business capability can be analyzed

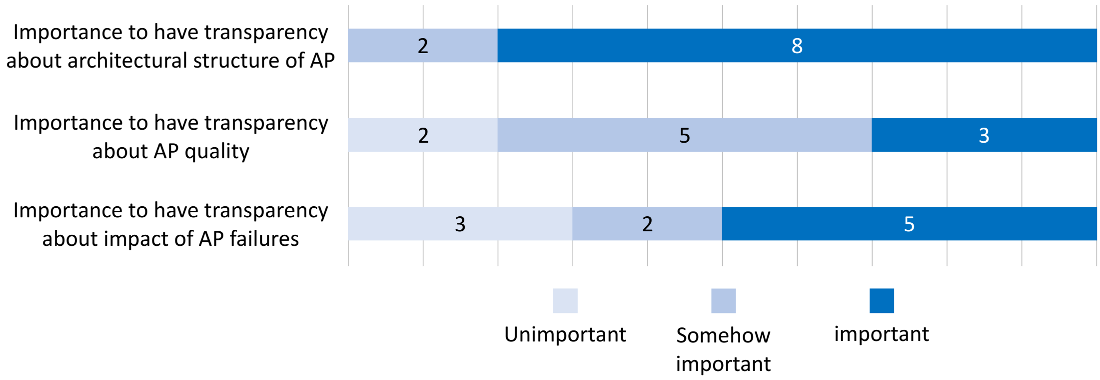

Figure 3.10.: Stated importance to measure APC from the suggested views (based on [Yi17])

more precisely by using the drill-down function to single APC indicators in terms of a root-cause analysis. Only a few questions arose during the presentation of the software solution. All participants understood the functionalities and the purpose of the visualizations quickly and the drill-down function attracted added attention. This perception is also manifested in the filled out questionnaires. The majority of the participants agreed that capability-based visualizations increase the transparency of APC issues and supports the identification of action areas (70%). The aggregated representation on a BCM helps to gain an overview of APC on a single page. Marking strategically important business capabilities helps to prioritize future projects. The drill-down function provides the possibility to zoom into single APC characteristics. However, one participant denied the added value of the shown visualizations: the expert stated that unnecessary dependencies between applications and redundancy in the AP are the main drivers of complexity. These dimensions are not reflected by the visualizations. The simple design of the software solution was considered by almost all participants as valuable. The operation is simple and information is limited to essentials. The drill-down function is presented intuitively and the Microsoft PowerPoint export makes the software solution suitable for everyday use.

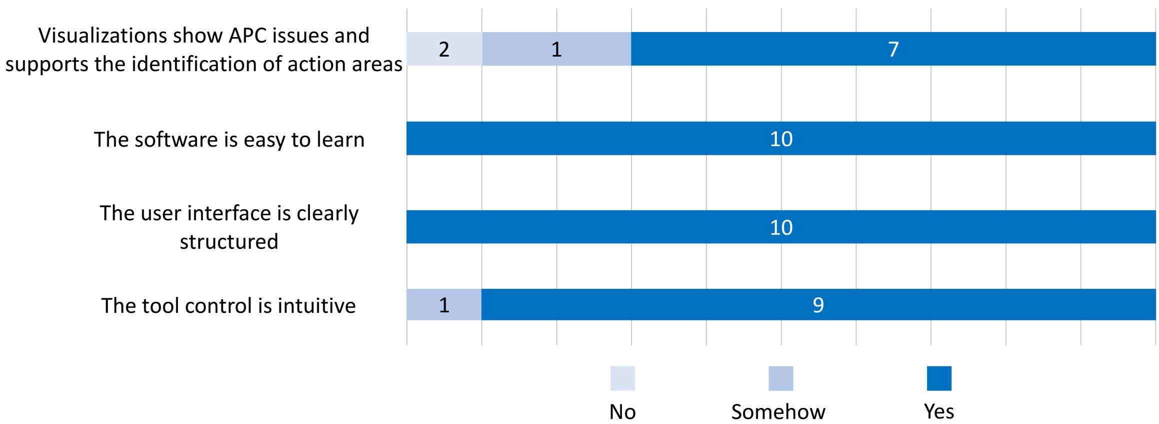

Figure 3.11.: Benefit of capability-based APC visualization with software support (based on [Yi17])

In the final part of the interviews, the KPIs were discussed once more. After the presentation, the participants had a concrete idea of the final artifacts and how the KPIs interact with capability-based visualizations. The equations of the KPIs were explained in detail and it was asked whether the KPIs, in combination with a capability-based visualization, provide transparency about APC. Figure 3.12 illustrates the results from the corresponding questions in the questionnaire. No participant considers the KPIs to fail. Although each KPI is supported by at least 50% of the participants, the results show that the KPI-based approach is not the best solution. The reasons for critique were largely the same for all three KPIs:

- The considered application characteristics are significant indicators for APC. However, the aggregation of several APC indicators into one KPI is not suitable, since they illustrate different issues.
- The idea of a capability-based visualization is helpful. However, it is recommended to define customized visualizations for individual APC indicators.
- The number of connections between applications and redundancy are important APC indicators. A fast identification of undesirable conditions with regard to these two APC indicators is not possible.
- It is important to take the opinions of experts into account, but the weights of APC indicators is insufficient and worth discussing.
- The notation of the Impact and Quality KPI is confusing. The terms are not clearly defined. The considered APC indicators are important but it is not clear why the selected APC indicators are suitable for the respective KPIs.

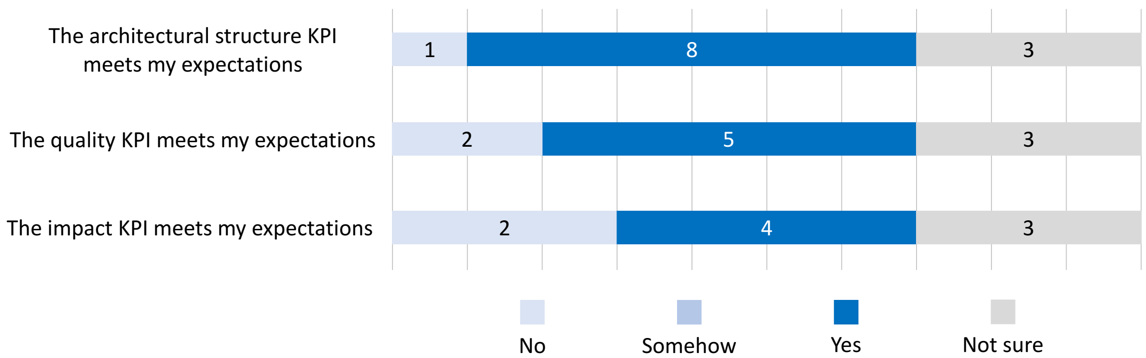

Figure 3.12.: Assessment of KPIs after the presentation (based on [Yi17]

Three participants did not answer these questions. They found it difficult to assess the quality of the KPIs conclusively. A discussion of the interview results is illustrated in the following section.

3.4. Key findings and lessons learned

Based on the foundations in Chapter 2, a capability-based APC management concept was introduced in Section 3.1. The concept aggregates APC indicators to three KPIs and visualizes the results of the KPIs with heat maps on a BCM. In order to evaluate the KPIs and the visualization concept, a case study was conducted with an automotive company. The case study considers genuine data of the automotive company (26 applications and original BCM of automotive company). Furthermore, a software solution was developed that visualizes the results of the KPIs on the BCM. Ten experts were interviewed to evaluate whether (1) the KPIs are meaningful (2) the visualization of APC on a BCM is useful and (3) whether the software solution brings added value. The interviews revealed the following results:

- **Selected APC indicators:** The experts agreed that the presented application characteristics are useful for APC. Most of the indicators are clearly measurable and provide good reference points to reduce APC (e.g. decrease the number of interfaces, decrease the number of used technologies)
- **KPI driven approach:** The illustration of APC with KPIs was criticized. The idea of aggregating several indicators into one KPI would be preferable but leads, in this case, to a biased picture: the APC indicators are individually important but their content is too different for an aggregation. Weighting the APC indicators is considered as beneficial, but there are no proven factors for the weights (subjective weights are not reliable enough). Significant APC indicators such as heterogeneity of the AP or application redundancies are not considered.
- **Capability-based visualization:** The approach was rated as very helpful. The visualization of APC on a BCM provides a simple and consistent picture. The drill-down function allows zooming from an aggregated view to individual components. All participants immediately understood the concept and confirmed that it provides an effective communication medium, which can be understood and used across the hierarchy.

Lessons learned

The evaluation has shown that the capability-based approach to visualize APC is useful, but experts distance themselves from the use of KPIs. They prefer visualizations that show the status of individual APC indicators. Most of the APC indicators were considered appropriate. The feedback served as input for a second case study. The capability-based approach was continued. The KPI approach was rejected and a number of visualizations for certain APC indicators had been defined. The revised approach is introduced in Section 4.1.

CHAPTER 4

Iteration 2: BCM with individual APC indicators

This chapter illustrates all conducted research steps and results of the second iteration. Section 4.1 explains the redesigned concept. The visualization identification process is documented in Section 4.2. All identified visualizations are explained in Section 4.3. The evaluation of the identified visualizations is explained in Section 4.4. In order to evaluate the visualizations, a second case study was conducted. The results of the case study are presented in Section 4.5.

4.1. Redesign

In the first iteration, several APC indicators were aggregated into one KPI and the corresponding results were visualized on the BCM. The corresponding visualization illustrates APC from one specific view (Architectural structure, Quality, Impact). Based on the feedback of the experts, this concept was redesigned: Figure 4.1 shows the redesigned concept.

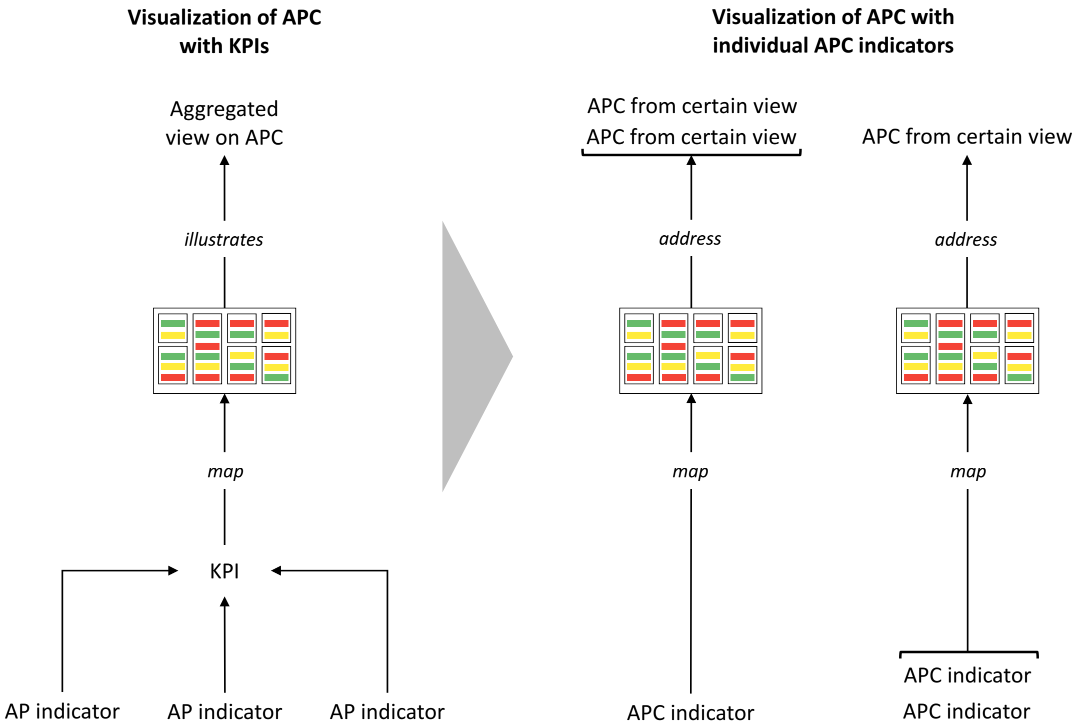

Figure 4.1.: Redesigned capability-based APC management concept

Experts asked for capability-based visualizations that address certain APC indicators, rather than results of aggregated KPIs. Based on group discussions with experts from the automotive company from the first case study and a further expert from an insurance company, 14 visualizations were defined. Each visualization addresses APC from certain views. The benefit and feasibility of each visualization were evaluated by conducting expert interviews with 25 organizations. The basic idea of using the BCM as the visualization medium and enabling a drill-down function has not changed. However, since the redesigned concept visualizes the status of certain APC indicators, the initial drill-down logic is no longer applicable anymore and has been adapted. The adapted visualization and the corresponding drill-down is explained in Section 4.5.2.1 in detail.

4.2. Visualization identification process

As mentioned above, the definition and evaluation of the visualizations was carried out in cooperation with an insurance company and the automotive company that already supported the first case study. The insurance company employs around 30,000 people and its EAM department introduced a BCM in 2015. The automotive company was already introduced in Section 3.1. Both companies have a good understanding of EAM, APC and the added value of BCMs. Their input complements knowledge from related work and the lessons learned from the first case study and ensures that the defined visualizations cover as many APC views as possible. The aim of the study was to discuss each visualization in detail with experts in this domain. Therefore, a qualitative research approach with expert interviews was chosen. The entire visualization identification process took 9 months and is shown in Figure 4.2.

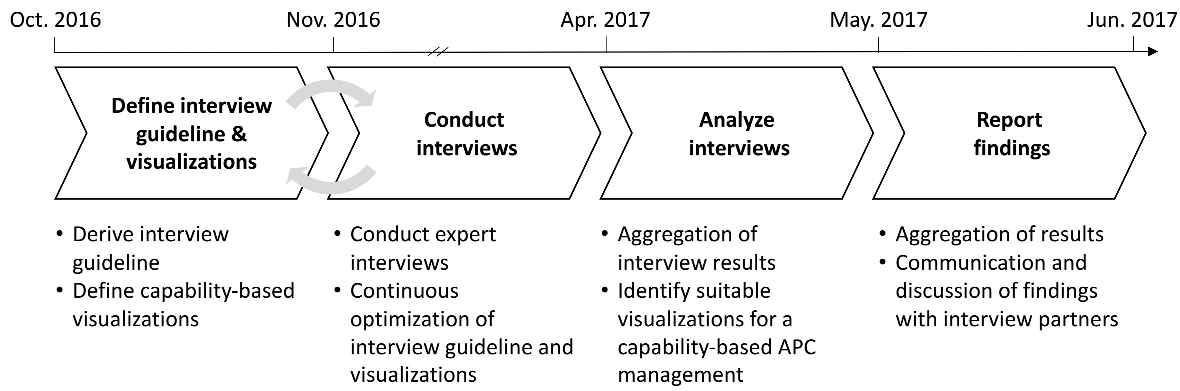

Figure 4.2.: Visualization identification process [AH18]

Define interview guideline & visualizations: The interview guide is divided into three sections: 1) General questions about the organization and the interviewee, 2) benefits and challenges of BCM in EAM, and 3) the evaluation of the individual visualizations. The aim of the interviews was to explore the research field from different perspectives and to let the participants talk freely about challenges and benefits of the single visualizations. Therefore, a semi-structured approach was chosen. To obtain a comparison of certain questions, multiple choice questions were also integrated. The interview guide is presented in Appendix A4.

Conduct interviews: Table 4.1 gives an overview of the interviewed experts. The participants were identified by a list of existing contacts from our research group and social media portals. All participants come from Germany and Switzerland. There was no focus on a particular industry so that the interviews could be interpreted independently of any context. When selecting the interviewees, we made sure only to consider participants who either already use BCM for EAM or were investigating the topic at that time. The interviews were scheduled for one hour each and were either conducted in person, via video conference or by telephone. However due to the high demand for discussions of the individual visualizations, most interviews last approx 1.5 hours. All participants received the interview guidelines about one week before the interview. After each interview it was evaluated whether it makes sense to extend the interview guide by adding further aspects.

Analyze interviews: The results of the interviews were documented in a concept matrix according to Webster and Watson. Microsoft Excel was chosen as the medium for documentation. The results were analyzed by interpretation analysis. The evaluation of the visualizations is important for this thesis and is illustrated in Section 4.4. For further results of the study, we refer to the corresponding contribution of our research group [AH18].

Report findings: The results were summarized in a Microsoft PowerPoint presentation and sent to all participants. All participants were offered a follow-up meeting to discuss the results. The findings from this study were crucial for the second iteration of this thesis: the evaluation of the individual visualizations had great influence on which visualizations should be considered in a second case study.

ID	**Industry**	**Head count (k)**	**Experience EAM (years)**
#1	Insurance	30	5
#2	Automotive	120	10
#3	Energy	60	6
#4	Financial services	60	12
#5	Financial services	13	6
#6	Insurance	44	8
#7	Logistics	500	10
#8	Chemicals	65	7
#9	Media	3.5	4
#10	Chemicals	17	4
#11	Telecom	225	10
#12	Information technology	380	18
#13	Consumer goods	57	3
#14	Telecom	150	25
#15	Insurance	10	8
#16	Conglomerate	350	>20
#17	Financial services	6	10
#18	Financial services	0.5	3
#19	Conglomerate	375	4
#20	Financial services	11	16
#21	Information technology	85	10
#22	Conglomerate	150	7
#23	Financial services	3.5	10
#24	Public sector	1	7
#25	Consumer goods	18	6

Table 4.1.: Overview of interviewed experts [AH18]

4.3. Identified visualizations

Table 4.2 gives an overview of all identified visualizations and shows which APC indicators are addressed by the individual visualizations. In the following sections, each visualization is explained in detail.

Visualization	Description	APC indicators
Application lifecycle	Identify capabilities with a high amount of applications with upcoming or reached retirement dates.	Application age
Application–extended support	Identify capabilities with a high amount of applications that are operated in extended support.	IT costs; Application age; Technical diversity; Deviation from standard
Capability spanning	Identify capabilities with a high amount of applications, which support more than one capability.	Capability coverage
Cost versus (vs.) user count ratio	Identify capabilities with a high amount of applications with a high cost vs. user count ratio.	IT costs; Number of users
Cloud candidates	Identify capabilities with a high amount of applications that should be operated in the cloud.	IT costs
Capability dependencies	Identify capabilities with a high amount of dependencies to other capabilities.	Number of interfaces; Application size
Harmonization potential	Identify capabilities with a high diversity of applications between different organizational units.	Functional overlap
IT costs	Sum of operation costs for each capability and ratio for each application.	IT costs; Number of incidents
Projects	Identify capabilities with a high amount of running projects.	IT costs
Business impact	Identify capabilities with high business value based on the impact of the underlying applications	Application failure.
Agile team organization	Identify capabilities with rigid team organization.	Capability coverage
Infrastructure components	Identify capabilities with a high amount of applications that use multiple infrastructure components.	IT costs
Infrastructure components–extended support	Identify capabilities with a high amount of infrastructure components in extended support.	IT costs; Deviation from standard
Compliance issues	Identify capabilities with high amount of applications with compliance issues.	

Table 4.2.: Overview of identified visualizations [AH18]

One visualization (*Compliance issues*) does not address APC indicators. However, the experts mentioned that the visualization of IT compliance issues on a BCM may be useful for their daily business and aksed to evaluate this visualization within the experts interviews as well.

4.3.1. Application lifecycle

Name:	Application lifecycle
Short description:	Identify capabilities with a high amount of applications with upcoming or reached retirement dates.
APC indicators:	Application age
Required data:	see Figure 4.4

Explanation: This visualization addresses the retirement date of applications. The age of an application is a complexity driver for application portfolios (e.g., high amount of customization and extended support costs) and applications nearing the retirement data should be addressed early by enterprise architects [AB16, AB17, Mo09a]. Heat mapping (red, yellow, and green) indicates which applications require further attention from a lifecycle point-of-view. A business capability that is supported by applications with no regular software support may lead to unnecessary costs due to extended support or security issues due to missing updates from software providers.

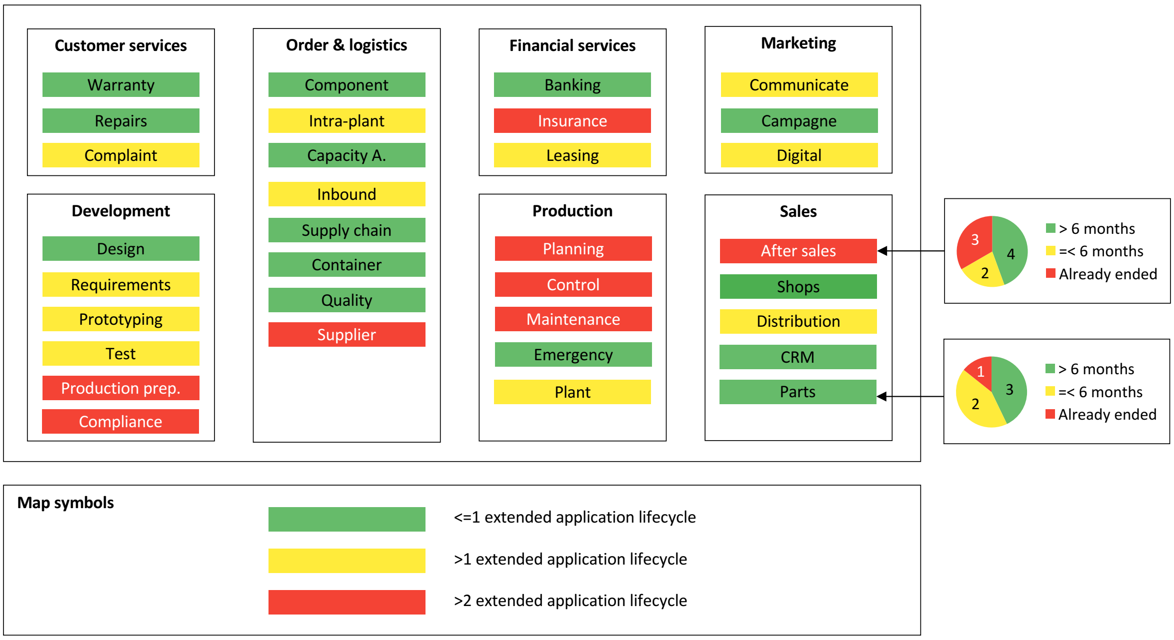

Figure 4.3.: Visualization: application lifecylce [AH18]

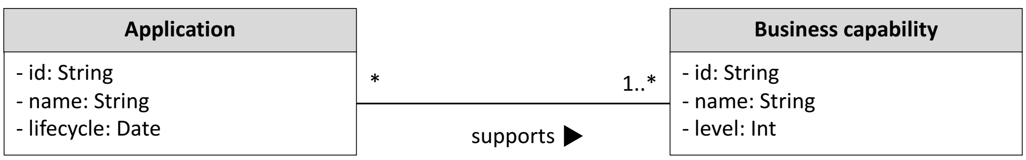

Figure 4.4.: Data model: application lifecylce

4.3.2. Application–extended support

Name:	Application–extended support
Short description:	Identify capabilities with a high amount of applications that are operated in an extended support.
APC indicators:	IT costs, application age, technical diversity, deviation from standard
Required data:	see Figure 4.6

Explanation: This visualization shows to what extent business capabilities are supported by applications that already operate with extended support. An application is operated with extended support when the vendor no longer provides regular support. Applications in extended support lead to increased costs (extra support), have an increased security risk (no patches from the manufacturer), do not usually meet the standard requirements of the organization and consequently lead to increased technical diversity, and indicate a respective age of an application. Heat mapping indicates to which extent a business capability is supported by applications with extended support.

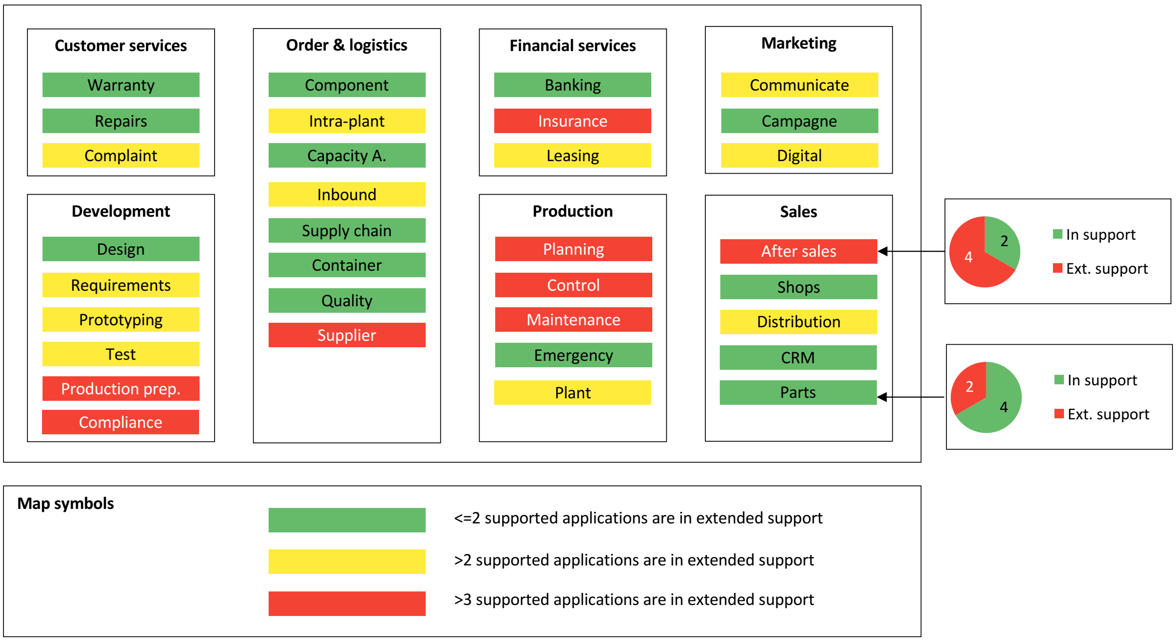

Figure 4.5.: Visualization: application–extended support [AH18]

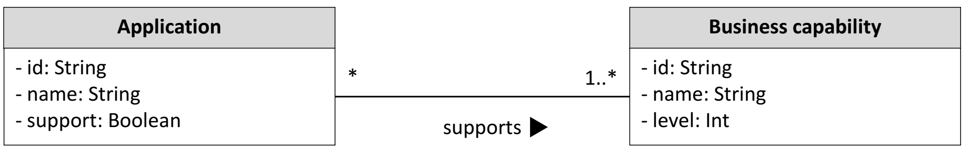

Figure 4.6.: Data model: application–extended support

4.3.3. Capability spanning applications

Name:	Capability spanning applications
Short description:	identify capabilities with a high amount of applications which support more than one capability.
APC indicators:	Capability coverage
Required data:	see Figure 4.8

Explanation: This visualization addresses the capability coverage of applications. Dependencies between applications are a much discussed APC indicator (see Table 2.5 for references) and applications that support multiple business capabilities indicate dependencies [AB16, Yi17, AH18]. Business changes in a business capability might affect other business capabilities through application connections. The AP should be oriented to the business capability structure and dependencies between business capabilities should be as low as possible. Heat mapping provides information on how many capability spanning applications support a business capability.

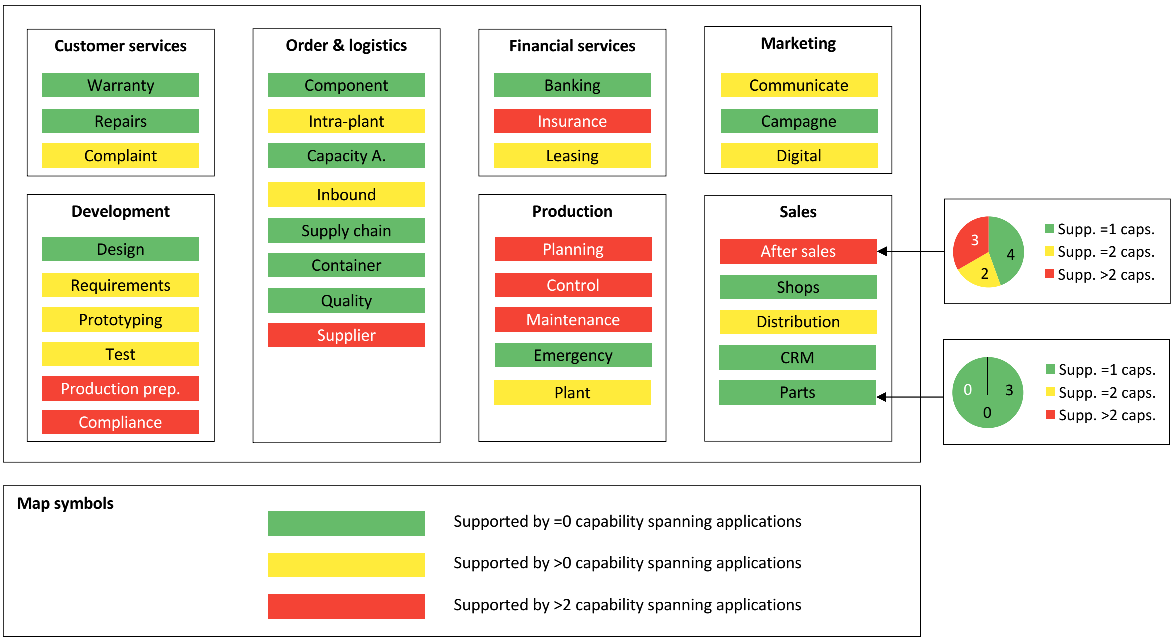

Figure 4.7.: Visualization: capability spanning applications [AH18]

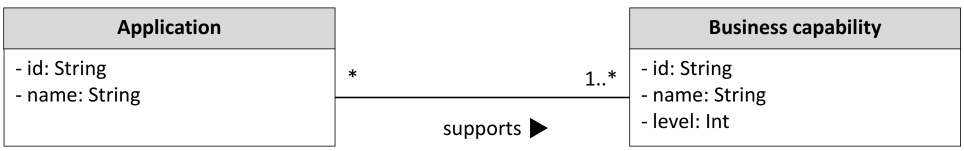

Figure 4.8.: Data model: capability spanning application

4.3.4. Cost vs. user count ratio

Name:	IT Costs vs. user count ratio
Short description:	Identify capabilities with a high amount of applications with high operation costs for less users.
APC indicators:	IT costs, number of users
Required data:	see Figure 4.8

Explanation: As shown in Table 2.5, costs and the number of users per application were identified as an APC indicator. Applications that are only used by a few users but have high IT costs are particularly disadvantageous. Such solutions should be evaluated for migration to other existing applications. The aim of this visualization is to identify business capabilities that are supported by a high amount of such applications.

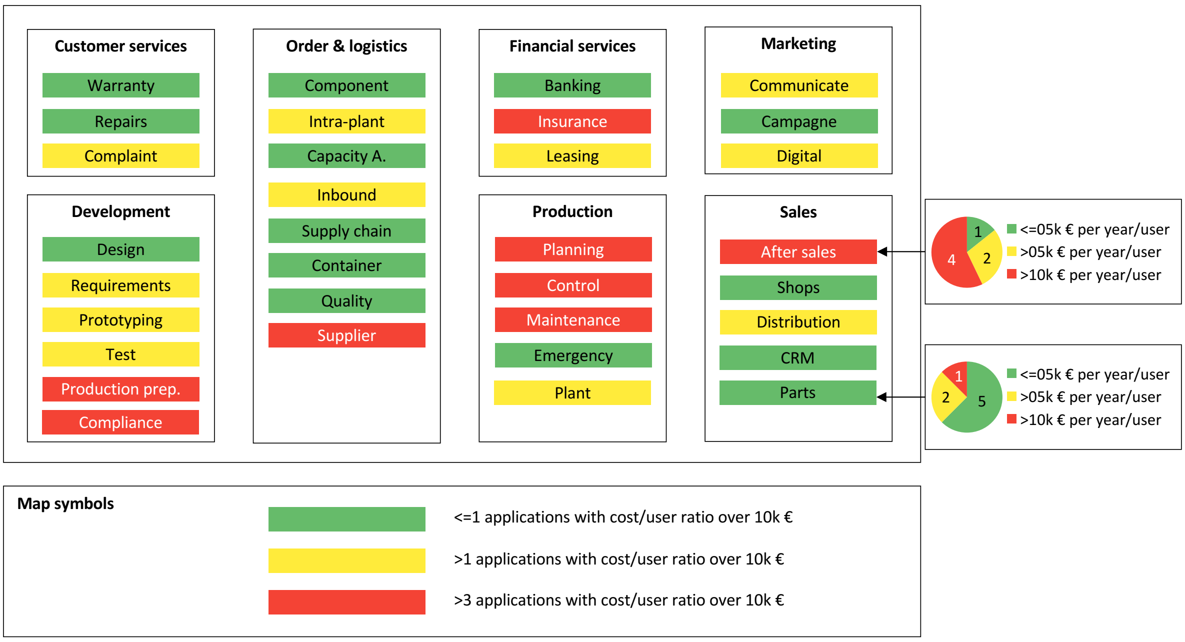

Figure 4.9.: Visualization: cost vs. user count ratio [AH18]

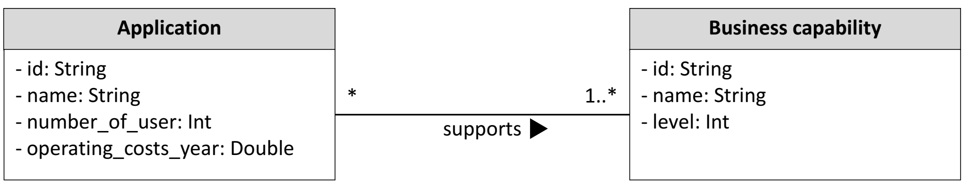

Figure 4.10.: Data model: cost vs. user count ratio

4.3.5. Cloud candidates

Name:	Cloud candidates
Short description:	Identify capabilities with a high amount of applications that should be operated in the cloud.
APC indicators:	IT costs
Required data:	see Figure 4.12

Explanation: Running applications in the cloud can increase both the effectiveness (outsourcing of business activities) and efficiency (costs) of AP operations [Gr09, AF10, WP10] This visualization shows in which business capabilities the supporting applications are operated in the cloud and where cloud candidates have not yet been migrated. A heat map on a business capability map shows to what extent existing applications within a business capability are operated in the cloud.

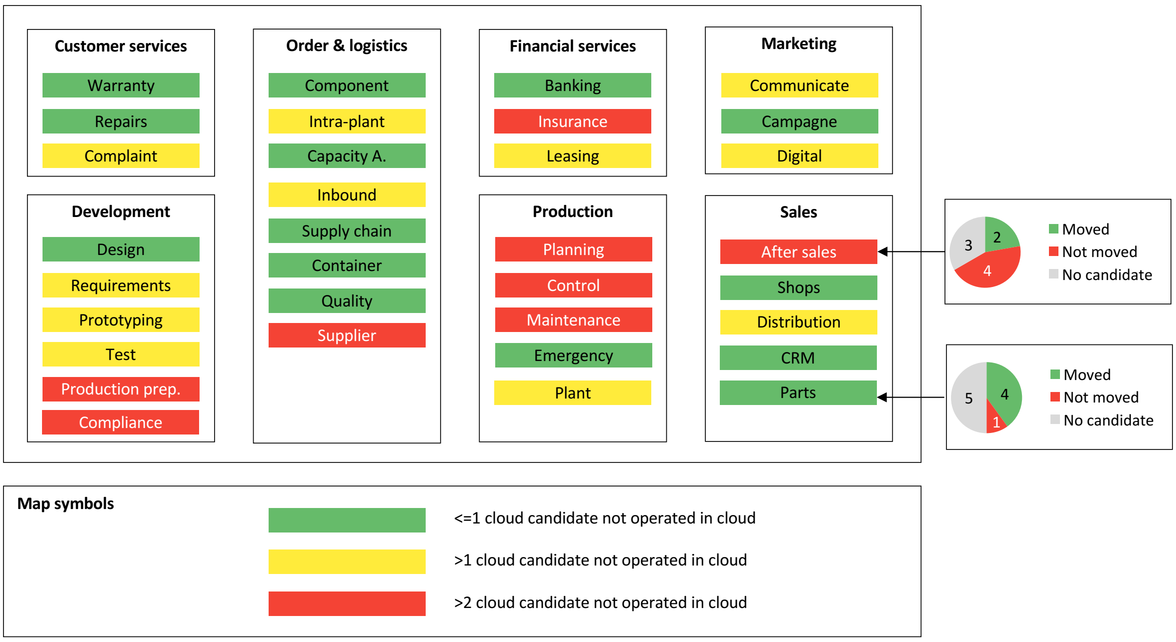

Figure 4.11.: Visualization: cloud candidates [AH18]

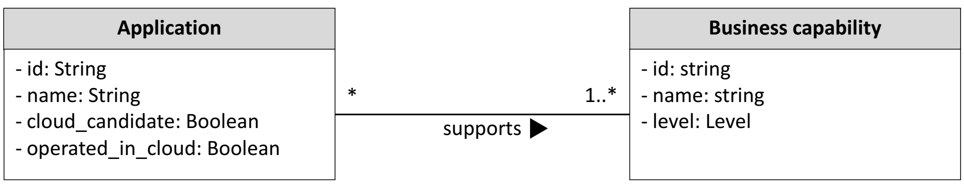

Figure 4.12.: Data model: cloud candidates

4.3.6. Capability dependencies

Name:	Capability dependencies
Short description:	Identify capabilities with a high amount of dependencies to other capabilities.
APC indicators:	Number of interfaces, application size
Required data:	see Figure 4.14

Explanation: Interfaces have already been mentioned several times in the literature as a APC indicator. Interfaces have been mentioned several times in literature as an APC indicator. In particular, dependencies between functional domains (in this case business capabilities) should be kept as low as possible: The AP should align to the BCM and business capabilities should be loosely coupled. Heat mapping can indicate how business capabilities are connected through interfaces.

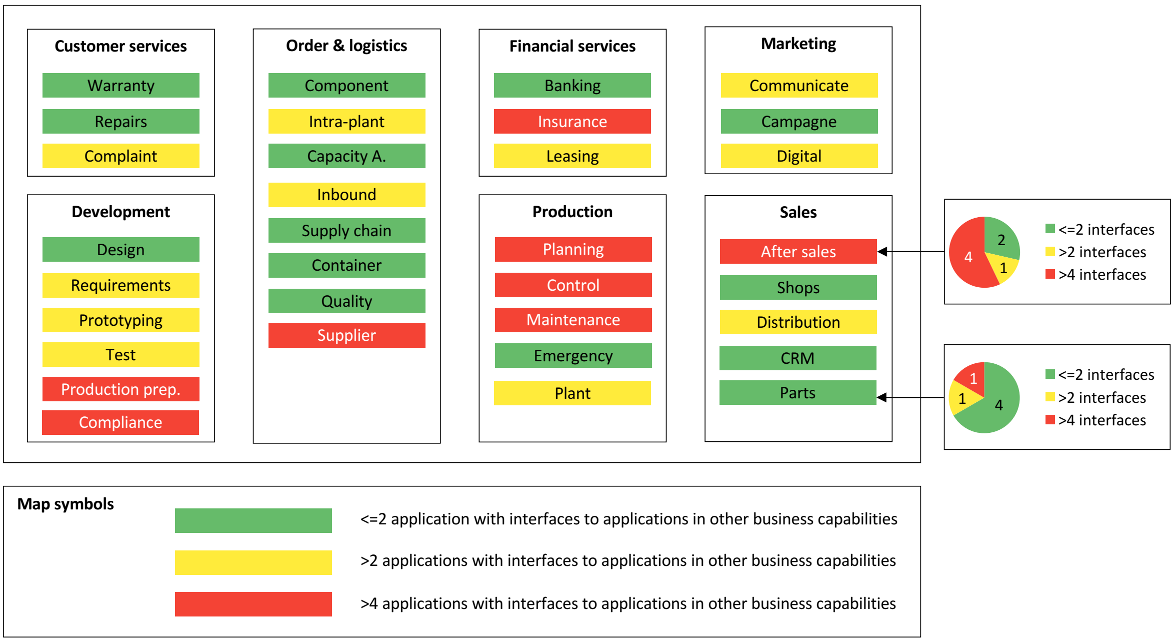

Figure 4.13.: Visualization: capability dependencies [AH18]

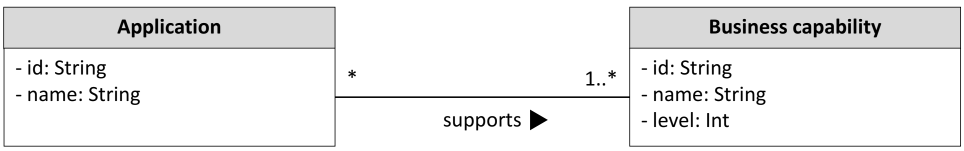

Figure 4.14.: Data model: capability dependencies

4.3.7. Harmonization potential

Name:	Harmonization potential
Short description:	Identify capabilities with high diversity of applications between different organizational units.
APC indicators:	Functional overlap
Required data:	see Figure 4.16

Explanation: Applications can support capabilities in different organizational units (or countries). Standardized solutions per capability are advisable. This visualization shows harmonization potential (several solutions for different organizational units for same business capability).

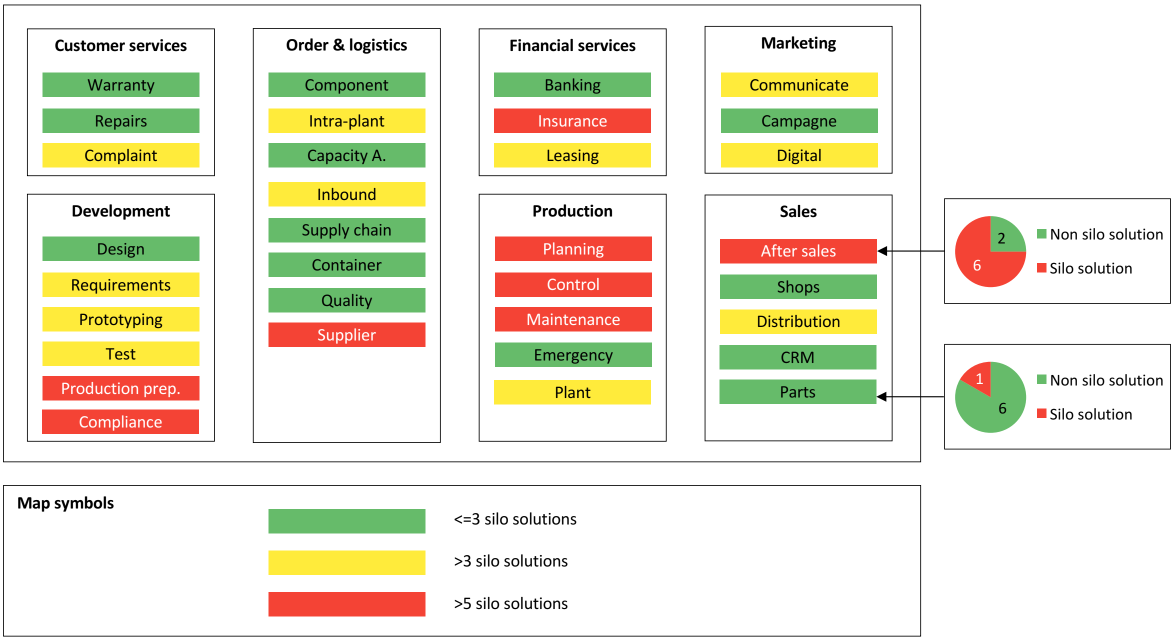

Figure 4.15.: Visualization: capability dependencies [AH18]

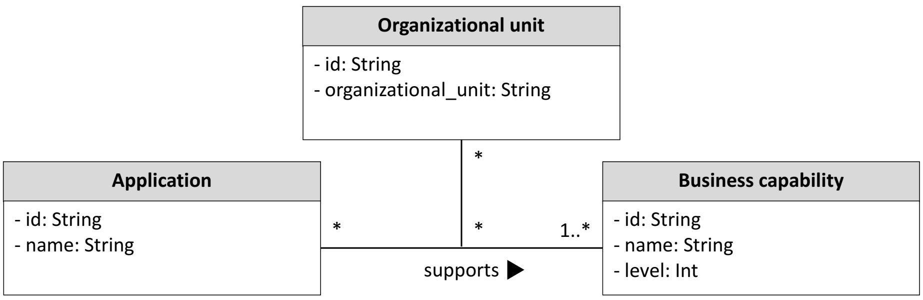

Figure 4.16.: Data model: capability dependencies

4.3.8. IT costs

Name:	IT costs
Short description:	Sum of application operation costs for each capability.
APC indicators:	IT costs, number of incidents
Required data:	see Figure 4.18

Explanation: IT costs are not a driver but effects of APC. Nevertheless, they provide a good indication of where architectural optimization (e.g. application elimination, consolidation, renewal) can reduce APC. In this visualization, costs are illustrated by operating costs of the used applications within a business capability. Heat mapping indicates the amount of application operation costs per business capability.

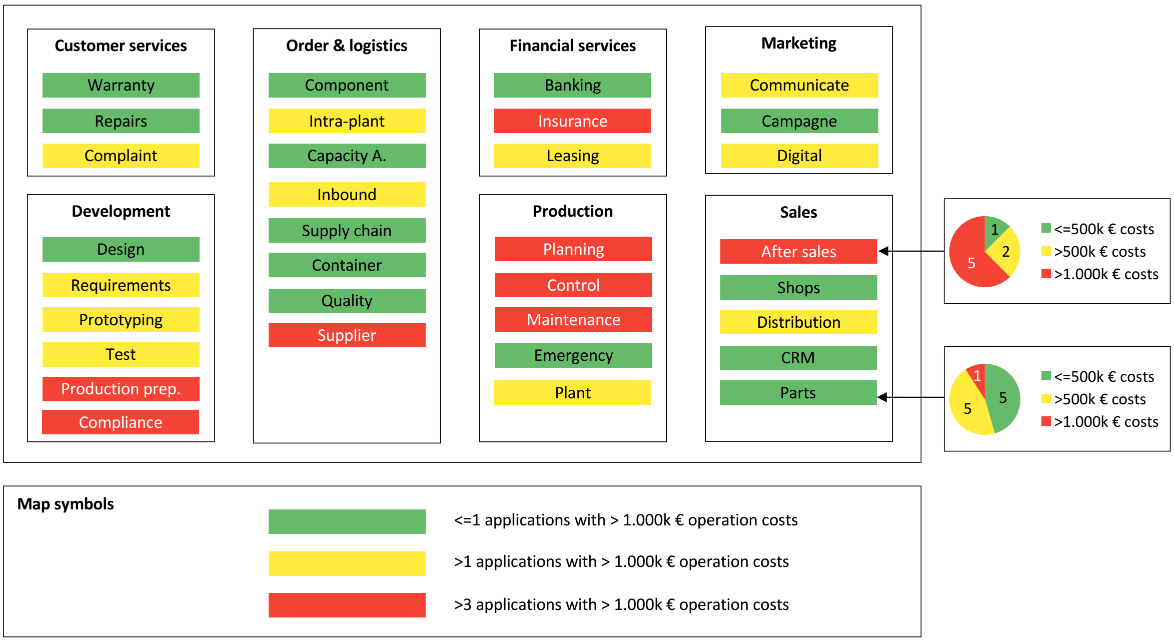

Figure 4.17.: Visualization: IT costs [AH18]

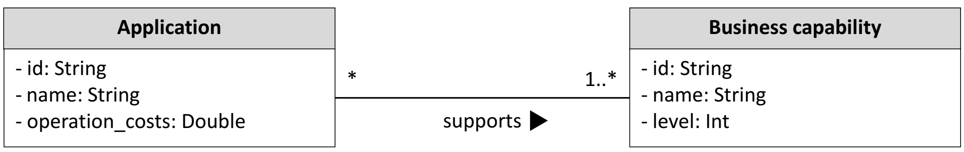

Figure 4.18.: Data model: capability dependencies

4.3.9. Projects

Name:	Projects
Short description:	Identify capabilities with a high amount of running projects.
APC indicators:	IT costs
Required data:	see Figure 4.20

Explanation: A large number of running (or planned) projects can indicate high IT costs or redundant projects. The visualization provides information on the current project status for each business capability. In this example, the project costs are crucial for the heat mapping .

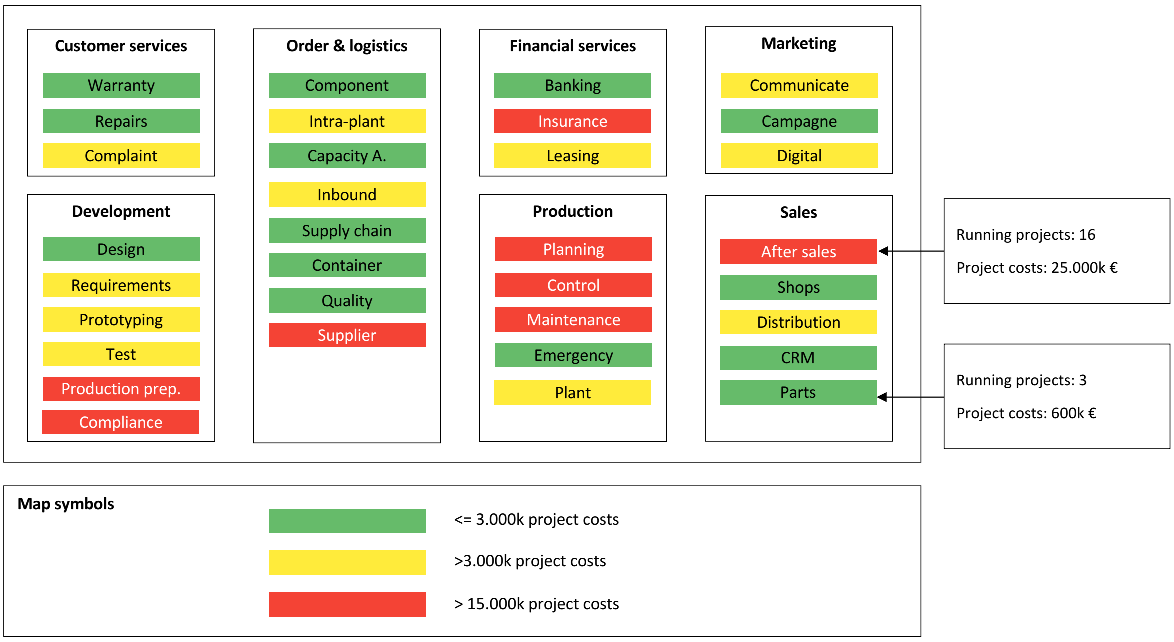

Figure 4.19.: Visualization: projects [AH18]

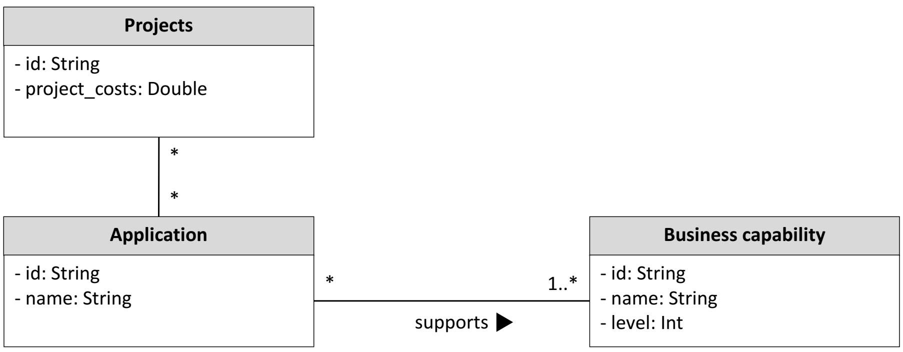

Figure 4.20.: Data model: projects

4.3.10. Business impact

Name:	Business impact
Short description:	Identify capabilities with high business value based on the impact of the underlying applications.
APC indicators:	Application failure
Required data:	see Figure 4.22

Explanation: Business impact analysis describes the effect of certain events in business operations [Ga17]. In this context, the business impact analysis of an application describes the financial effect on business operations in case of failure. This visualization shows the business impact of business capabilities based on the business impact of the underlying applications. The higher the aggregated business impact of the underlying applications, the higher the business impact of the business capability. In combination with other key figures (e.g. critical incident tickets) this visualization can help to prioritize APC reduction initiatives.

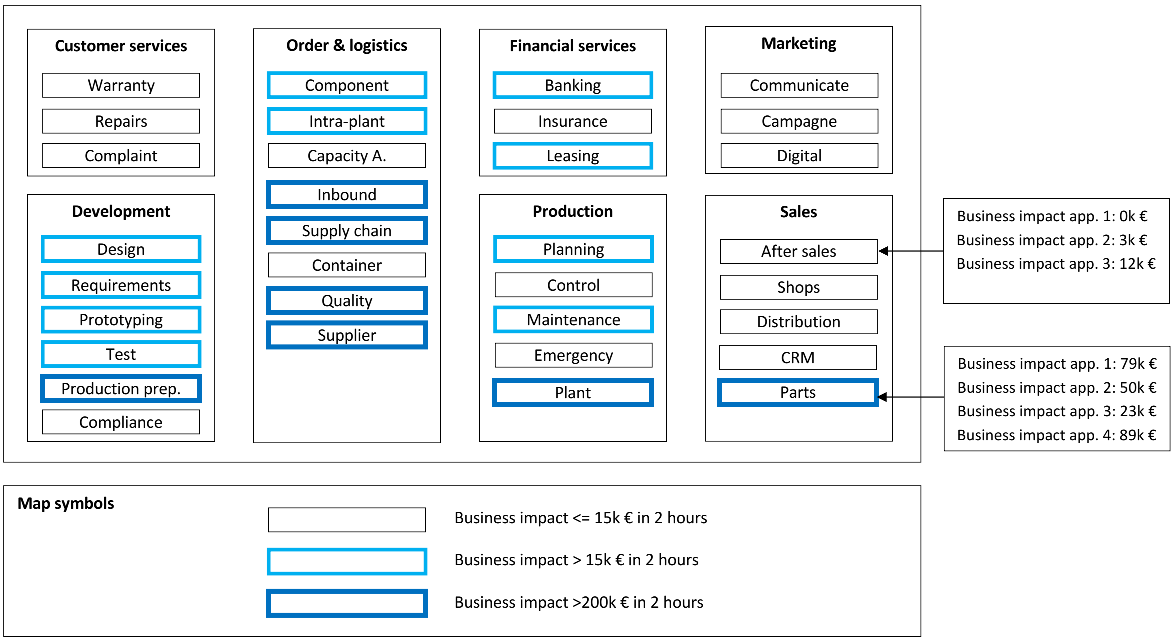

Figure 4.21.: Visualization: business impact [AH18]

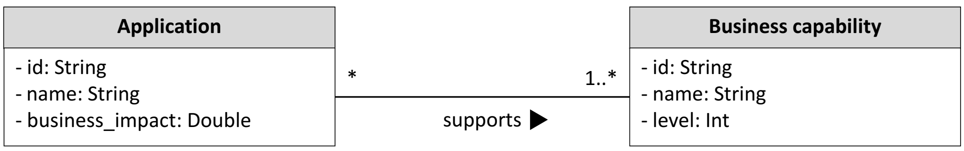

Figure 4.22.: Data model: business impact

4.3.11. Agile team organization

Name:	Agile team organization
Short description:	Identify capabilities with rigid team organization.
APC indicators:	Capability coverage
Required data:	see Figure 4.20

Explanation: The insurance company uses the BCM to manage the staffing of agile teams: when a team is working on an application within a project, user stories are mapped to the BCM. User stories that support different business capabilities can mean the following: either the products or the teams are defined incorrectly or the AP does not align to the BCM. In both cases there may be overlaps between teams and consequently redundancies in the AP.

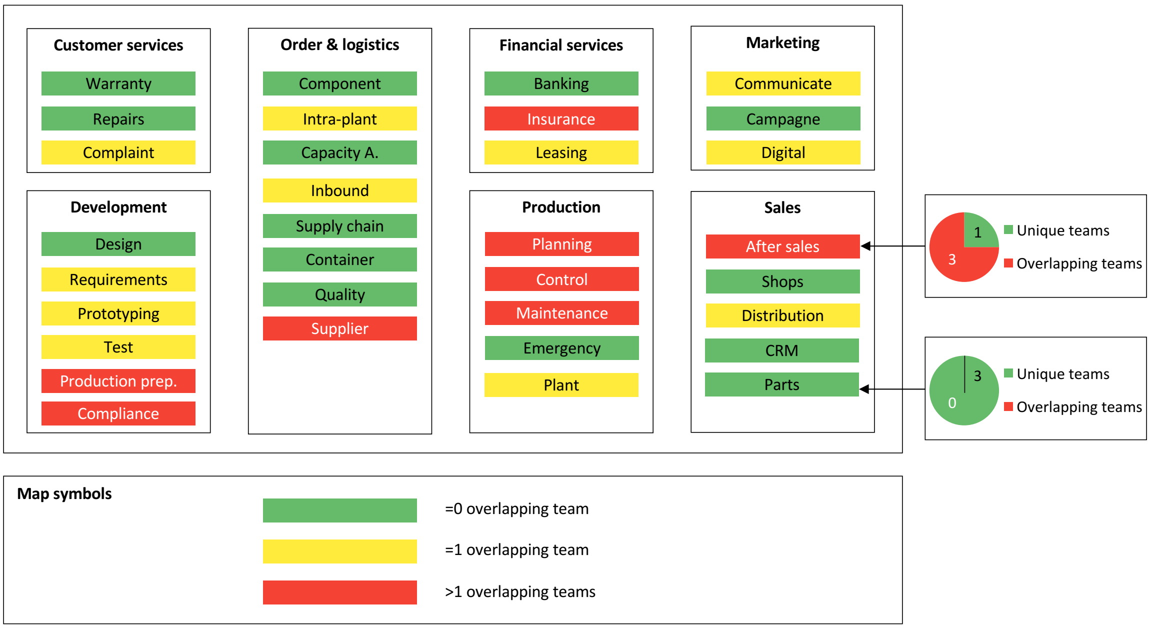

Figure 4.23.: Visualization: agile team organization [AH18]

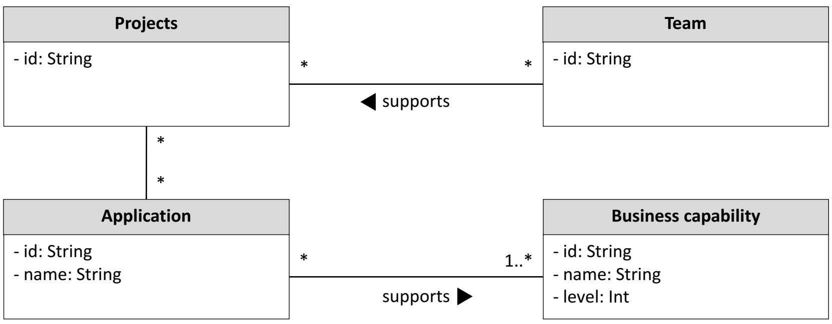

Figure 4.24.: Data model: agile team organization

4.3.12. Infrastructure components

Name:	Infrastructure component
Short description:	Identify capabilities with a high amount of applications that use multiple infrastructure components.
APC indicators:	IT costs
Required data:	see Figure 4.26

Explanation: This visualization highlights capabilities which are supported by applications with multiple infrastructure components. The higher the number of infrastructure components, the higher the operating costs of the applications.

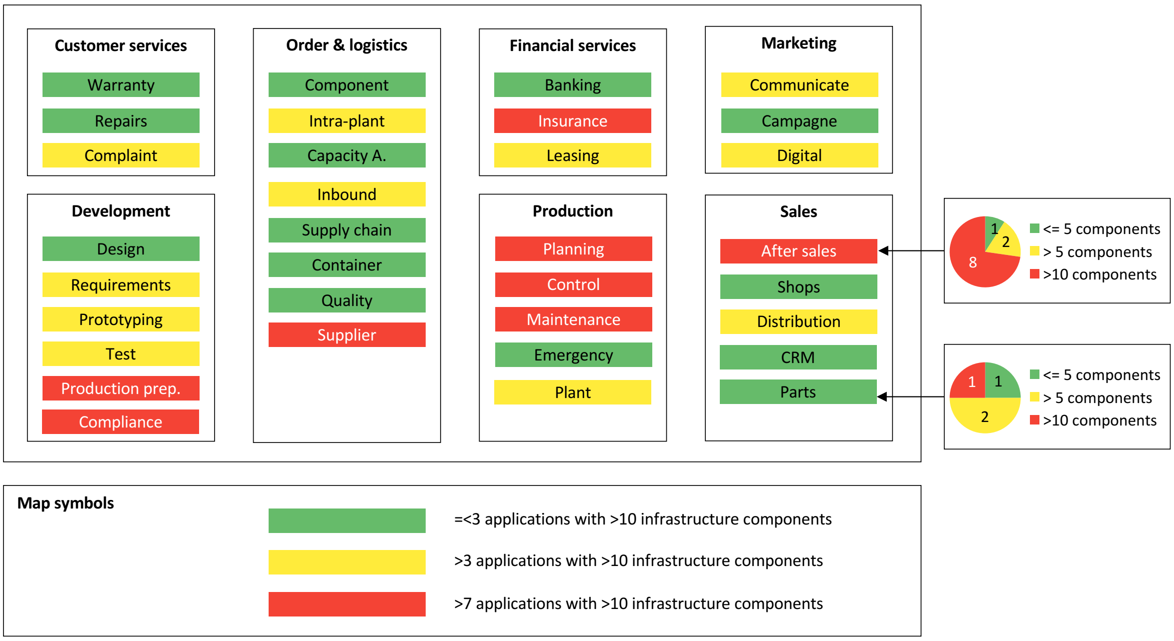

Figure 4.25.: Visualization: infrastructure components [AH18]

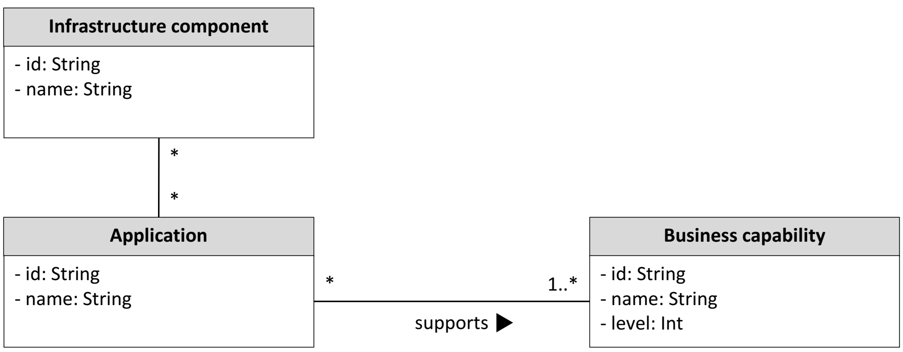

Figure 4.26.: Data model: infrastructure components

4.3.13. Infrastructure components–extended support

Name:	Infrastructure component–extended support
Short description:	Identify capabilities with a high amount of infrastructure components with extended support.
APC indicators:	IT costs; deviation from standard
Required data:	see Figure 4.28

Explanation: This visualization shows which capabilities are supported by applications that use infrastructure components with extended support. Components that are no longer supported by the vendor do not normally meet standard specifications of organizations and are expensive to support.

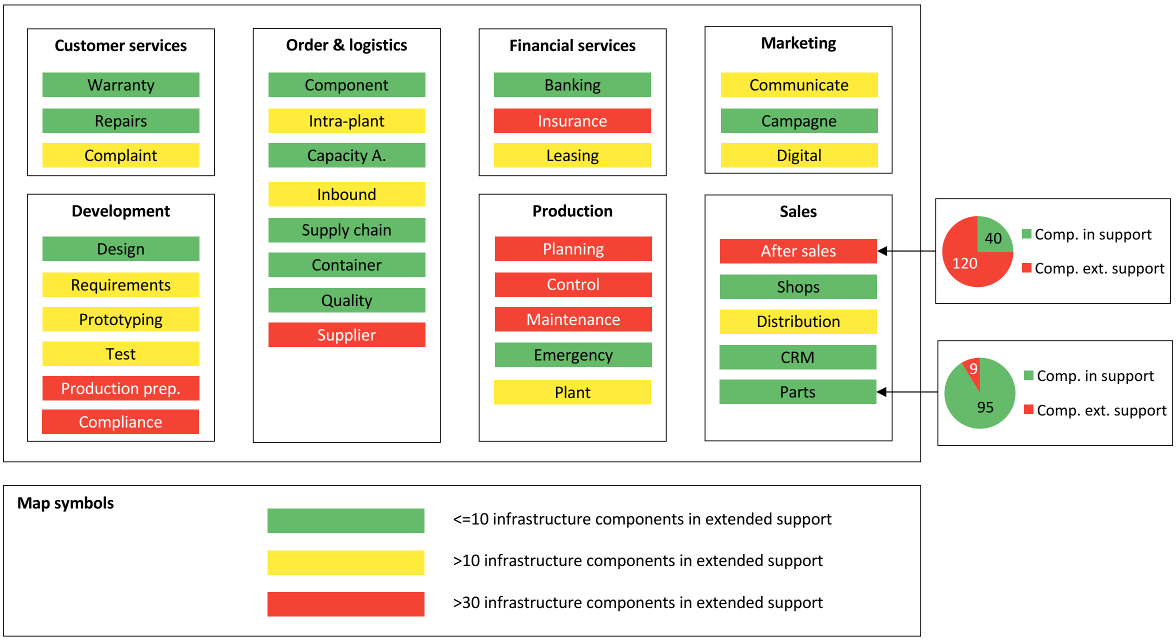

Figure 4.27.: Visualization: infrastructure components–extended support [AH18]

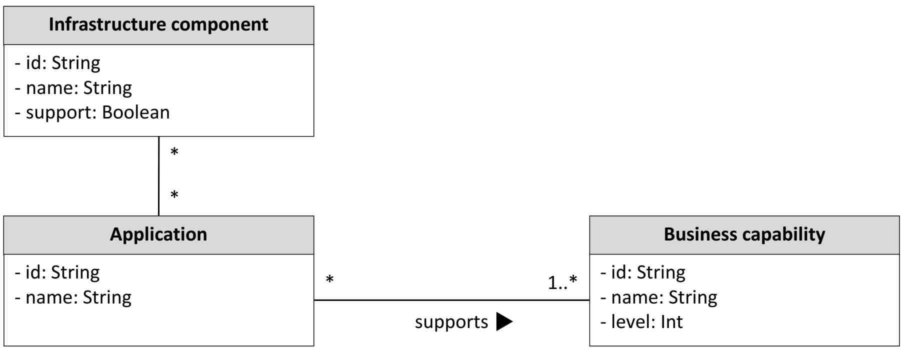

Figure 4.28.: Data model: infrastructure components–extended support

4.3.14. Compliance issues

Name:	Compliance issues
Short description:	Identify capabilities with a high amount of applications with compliance issues.
APC indicators:	
Required data:	see Figure 4.28

Explanation: This visualization was defined at the request of the industry partners and has no direct reference to APC. The visualization highlights business capabilities which are supported by applications with numerous compliance issues.

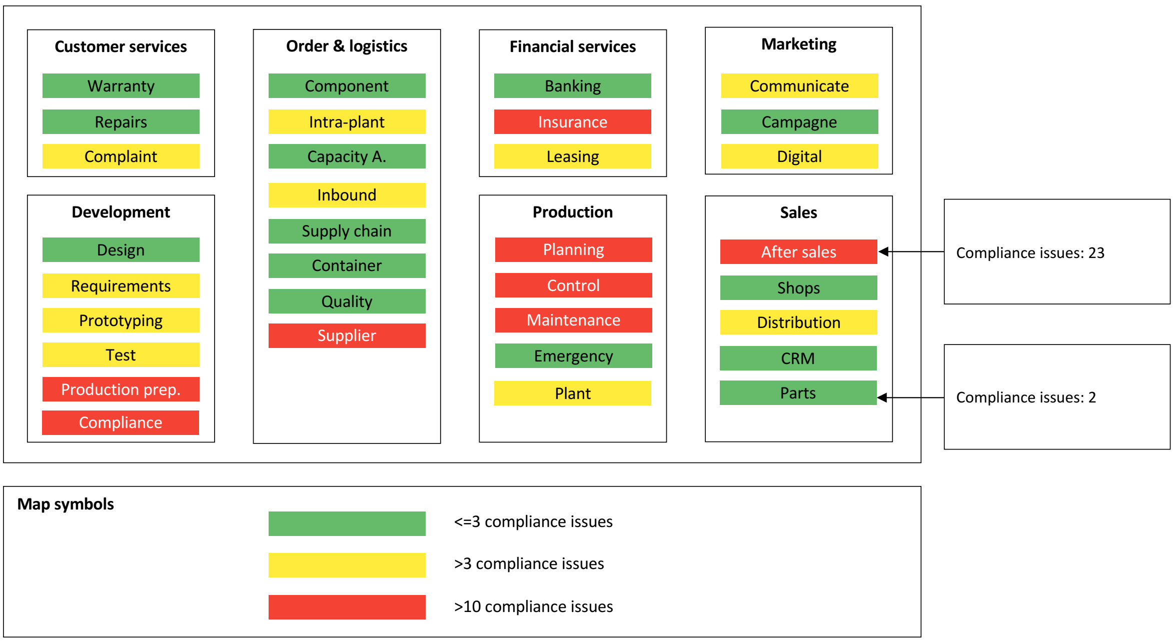

Figure 4.29.: Visualization: compliance issues [AH18]

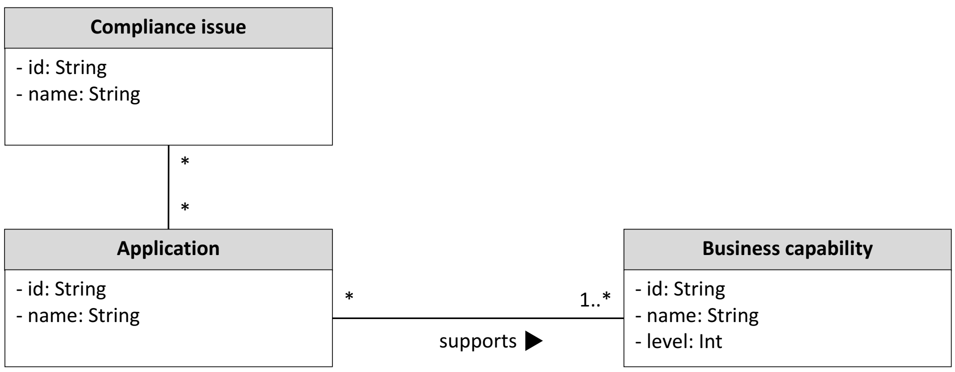

Figure 4.30.: Data model: compliance issues

4.4. Evaluation by expert interviews

For each visualization, the experts were asked whether the organization they work for 1) already implemented the respective visualization, 2) plans to implement it or 3) if no implementation is planned. Figure 4.31 shows the results of the interviews.

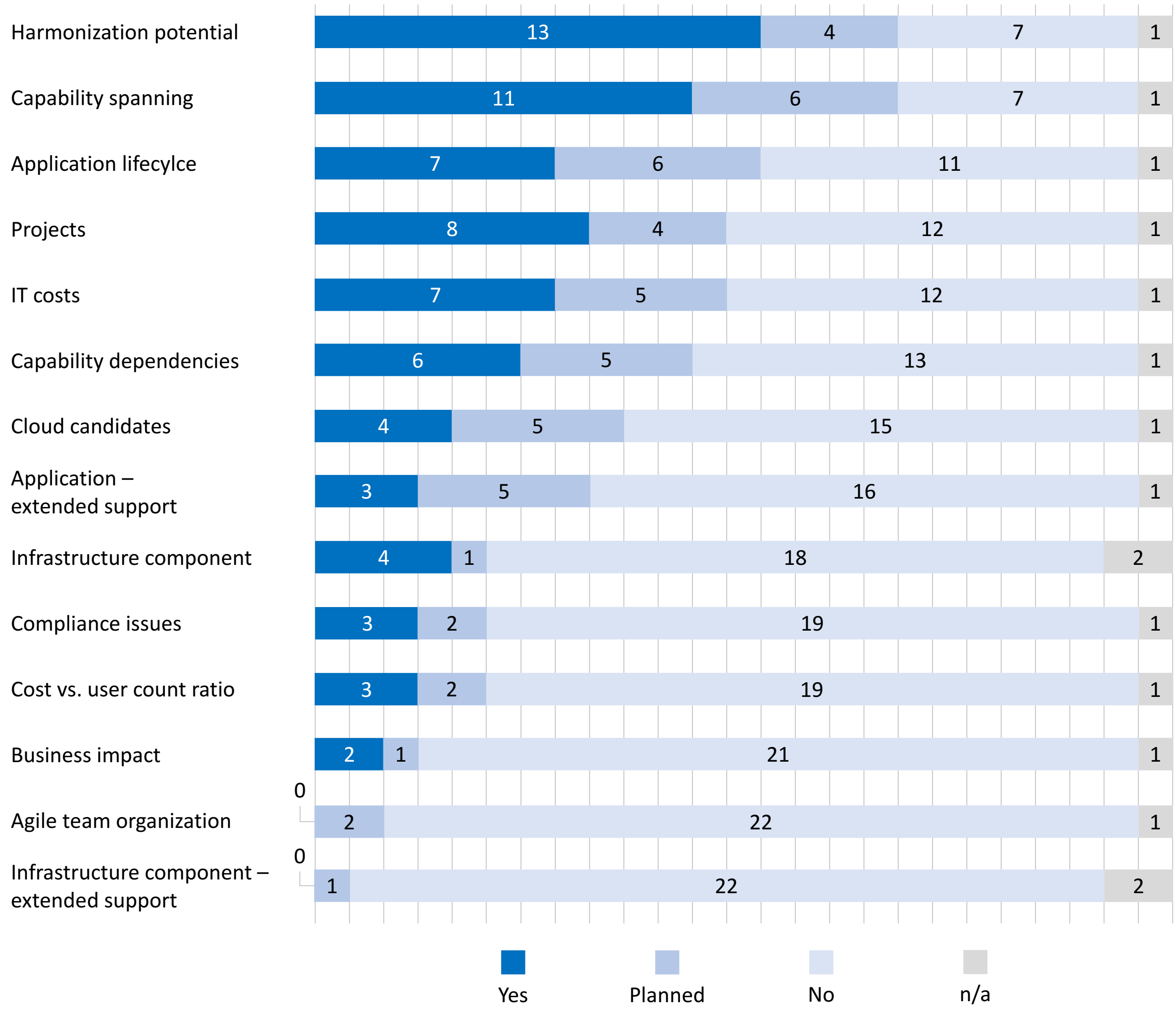

Figure 4.31.: Visualization use in practice [AH18]

The results show visualizations that allow cross-portfolio analysis (capability spanning and harmonization potential) and enable decisions based on expenses (projects and IT costs) have mostly been implemented. The results also show the novelty of the approach: many visualizations were rated as *planned* which shows that companies are currently dealing with the concept. Two visualizations are not implemented by any of the experts (agile team organization and infrastructure component – extended support). Findings from these visualizations do not allow enough insights on APC. AP and architectural decisions are mainly driven by expenses, AP heterogeneity, and harmonization possibilities.

In the interviews, the experts were asked to rate each visualization in terms of benefit and feasibility (scale: 1= very low, 2= low, 3= high, 4= very high). The implementation effort can be influenced by various factors (existing data quality, implementation effort). A visualization is beneficial if the transparency of APC increases and actions can be derived in a more targeted way. The results were used to calculate a benefit/feasibility rating for each visualization. The results are illustrated in Figure 4.32. Each rating is placed in one out if four quadrants. The equation is shown at the bottom right corner of the figure.

- Upper right: high benefit/high feasibility
- Lower right: high benefit/low feasibility
- Lower left: low benefit/low feasibility
- Upper left: low benefit/high feasibility

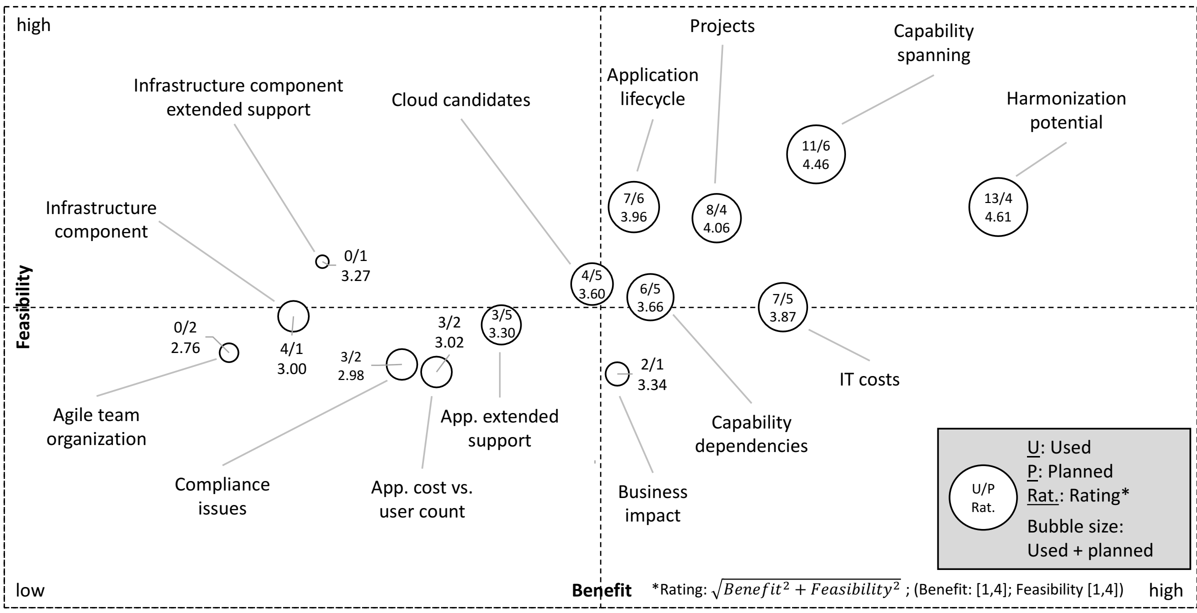

Figure 4.32.: Visualization benefit/feasibility rating [AH18]

Each rating is presented in a bubble. The size of the bubble shows how many organizations already implemented, or plan to implement, the respective visualization. The visualizations in the upper-right quadrant (high benefit and feasibility) are of particular interest. Visualizations in the lower-left quadrant are not particularly useful (low benefit and feasibility). The participants said that for these visualizations the data is not available and the provided visualization does not help to derive useful actions. The results of this study were important for this thesis for two reasons: 1) they confirm the usefulness of the capability-based approach for this field of research and 2) they help to decide which visualizations are considered to be useful and which not. The benefit/feasibility rating was used to specify a second case study with the automotive company.

4.5. Case study

The automotive company from the first case study served once more as the case study partner. The case study can be divided into three parts: 1) identification of appropriate visualizations and data collection (cf. Section 4.5.1), 2) implementation of a software solution (cf. Section 4.5.2), and 3) evaluation of the results (cf. Section 4.5.3). The case study setup aligns to the same environment of the first case study (specifications according to Yin [Yi13], single case study, semi-structured questions in evaluation, etc.).

The case study was conducted cooperating closely with the industry partner: the visualizations to be implemented were selected in cooperation with experts from the automotive company and the redesigning of the software solution (drill-down view) is based on requirements analysis, which was realized through group discussions with three experts of the same organization. The evaluation is based on interviews with 13 experts from the automotive company.

4.5.1. Visualization selection and data collection

In cooperation with four EA experts from the automotive company, possible visualizations for evaluation were discussed. The results of the conducted survey (cf. Section 4.4) served as important input. Based on the availability of data and the assumed added value for the organization, four visualizations were chosen for the evaluation:

- Application lifecycle
- Harmonization potential
- Capability spanning application
- Cloud candidates

The dataset for this case was very rich: the automotive company has its own financial service division which operates in 24 countries (markets). The division is supported by 1,015 applications. The provided dataset was of high data quality and provides the following information: 1) in which market an application supports a specific business capability, 2) start and end time of the application lifecycle, and 3) whether the application is operated in the cloud or not. Figure 4.33 illustrates a respective data model. Since the visualizations highlight the status of individual APC indicators, less information was needed from the EA repository. Consequently, the data model is simpler than the model of the first iteration (cf. Figure 3.5). The data could easily be extracted from the EA repository. There was no need for extensive data cleansing activities. In cooperation with two EA experts from the automotive company, heat mapping rules were defined for each visualization (cf. Section 4.5.2.2). The heat mapping rules consider color codes for business capabilities (needed for business capability view) and applications (needed for drill-down view). The heat mapping rules are presented in Table 4.4, 4.5, 4.6, and 4.7.

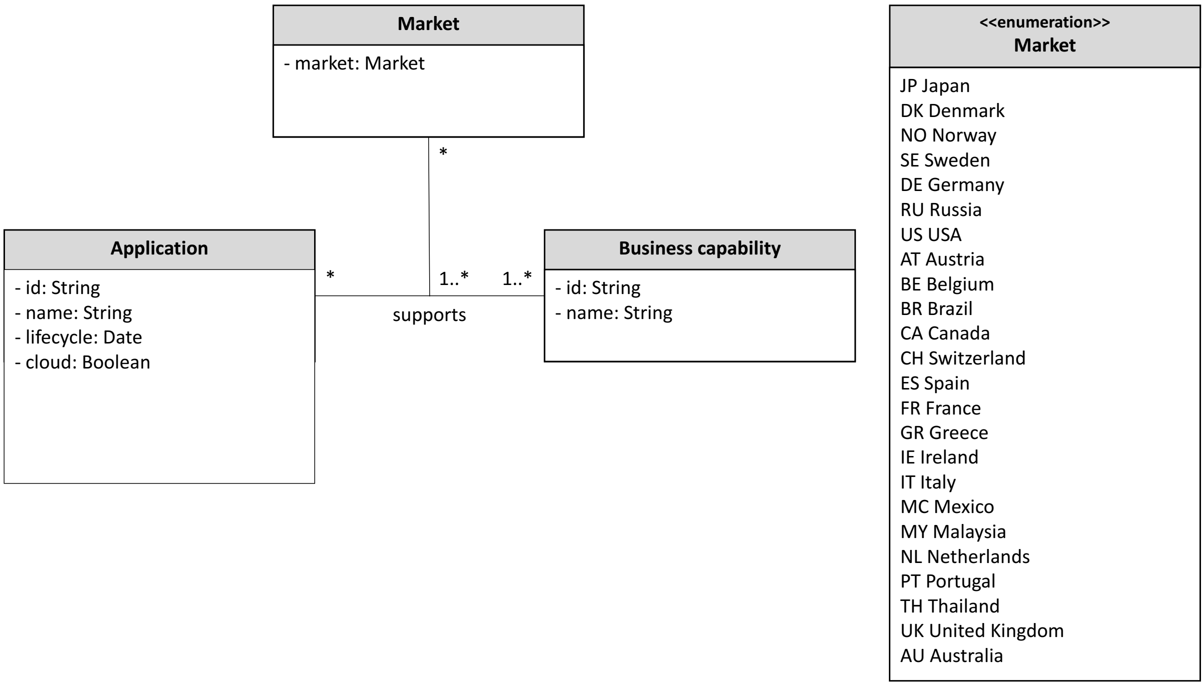

Figure 4.33.: Data model for redesigned capability-based APC management using APC indicators

4.5.2. Tool re-implementation

The implemented tool is based on the deployed solution of the first iteration. The BCM was not changed and could be adopted. The changes refer to the introduced heat mapping rules and a new drill-down design. The main changes are highlighted in Figure 4.34. The *Raw data and model* layer are represented by the extracted AP information from the automotive company and the defined data model (cf. Figure 4.33). The *Analytical abstractions* are illustrated by heat mapping rules for the BCM and drill-down visualizations. Since four visualizations were selected for implementation and each of them contains a drill-down view, eight heat mapping rules were defined (cf. Section 4.5.2.2). The *Visualization abstractions* illustrate the heat maps for business capabilities and applications. The *Views* layer represents the final visualization and drill-downs in the front-end.

As in the first iteration, all information and layers were directly implemented in the source code of the software and no independent models or roles have been defined for each layer: The software is primarily used to evaluate the approach and to show what a software solution can look like. A prototype development is sufficient. An over-engineered definition of multiple layers and responsibilities is out of touch with the practice. The industry partner has a more pragmatic EAM (a core EA model that is implemented in the EA repository, few EA modeling experts who are responsible for all layers in the model). The required data is imported from a Microsoft Excel file, which stores the AP data.

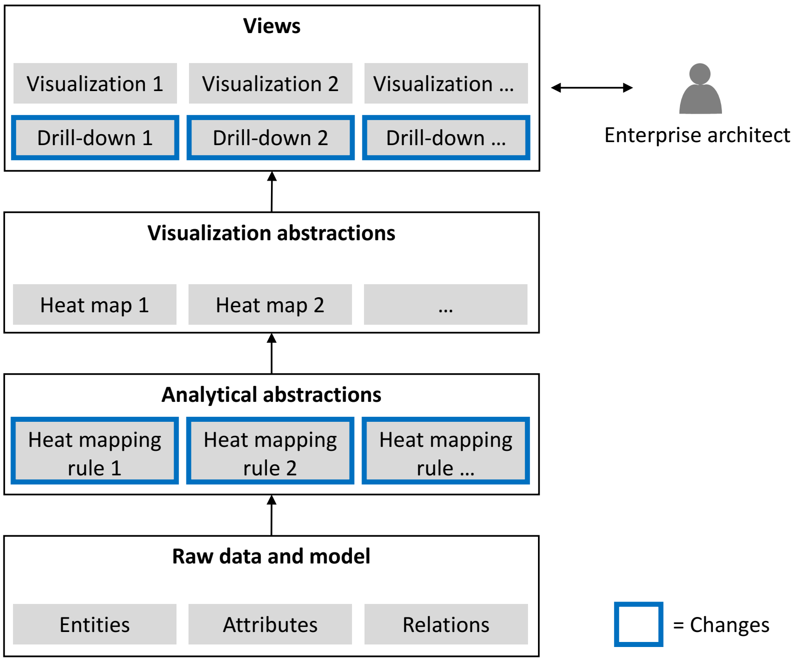

Figure 4.34.: Capability-based APC management concept using APC indicators (based on [CR98, Re17])

4.5.2.1. Identified requirements

In order to concrete the design of the visualizations, drill-downs and heat mapping rules, functional and non-functional requirements were identified through group discussions with experts from the automotive company. The documentation aligns to the template of Robertson and Robertson [RR00]. There was, again, a distinction between different types of requirements (Interaction, business capability visualization, etc.). The identified requirements are documented in Table 4.3.

11 functional requirements were identified. The definition of the requirements could be carried out much faster in the second iteration: the case study partner is the same organization from the first iteration and the software on which the further development takes place was already known. Many functional requirements remained unchanged. The changes mainly relate to the fact that the heat mapping rules have changed (from KPIs to basic limit values) and the drill-down view has been redefined. The non-functional requirements have not changed and are not listed repeatedly (cf. Table 3.13). Various requirements could already be realized with the implementation. During the requirements analysis, it turned out that the company's financial service unit could be divided into two divisions (general service and fleet management). The differentiation between these two units was desired by the industrial partner (cf. FREQ–2).

Type	ID	Name	Description	Fit criterion
Interaction	FREQ–1	PowerPoint export	Visualizations should be exportable.	Generated visualizations can be exported to a Microsoft PowerPoint .pptx file.
	FREQ–2	Select operational unit	The user can select an operational unit for the analysis.	The front end provides a drill-down menu to select an operational unit for the analysis.
	FREQ–3	Select visualization	The user can select one out of four visualization for the analysis	The front end provides a drill-down menu to select one out of for visualizations for the analysis.
	FREQ–4	Drill-down	The user wants to identify root causes for business capability assessments in the AP	The software provides a drill-down function (business capability to applications).
Business capability visualization	FREQ–5	Layout	The user should quickly find and his way through the visualization.	The original design of the company's BCM is considered within the visualization.
	FREQ–6	Color coding	The user has to be able to interpret the APC and derive suitable actions based on color coding	The respective APC is visualized by the colors red (poor), yellow (medium), and green (good).
	FREQ–7	The APC status is calculated for level-1 business capabilities	The visualization reveals the APC status only for level-1 capabilities.	The business capabilities illustrate the APC from a certain viewpoint (one out of four visualizations) based on color coding for the business capabilities.
AP visualization	FREQ–8	Application lifecycle	Applications with an exceeded lifecycle can be identified	Definition of a suitable color coding on application level.
	FREQ–9	Harmonization potential	Redundant applications within a business capability can be identified	Definition of a suitable color coding on application level.
	FREQ–10	Capability spanning application	Applications that support multiple business capabilities can be identified	Definition of a suitable color coding on application level.
	FREQ–11	Cloud candidates	Potential cloud candidates can be identified	Definition of a suitable color coding on application level.

Table 4.3.: Overview of functional requirements

A crucial change is the drill-down view. In the solution from the first iteration, a list of supported applications could be displayed by clicking on a L2 business capability (cf. Figure 3.6). By clicking on an application, the application characteristics were displayed. A heat map on each level (L2 business capability, application, application characteristics) enabled a root cause analysis. A drill-down to application characteristics is no longer necessary, since the visualizations consider individual APC indicators. It is important to show which business capabilities are supported by individual applications and whether an application is used for a specific market or across multiple markets. This information is important for the visualizations capability spanning applications and harmonization potential. Figure 4.35 illustrates the redesigned drill-down view. Major changes to drill-down are:

- The drill-down starts at L1 and not L2 business capabilities
- Drill-downs show which application supports which business capability for which market.

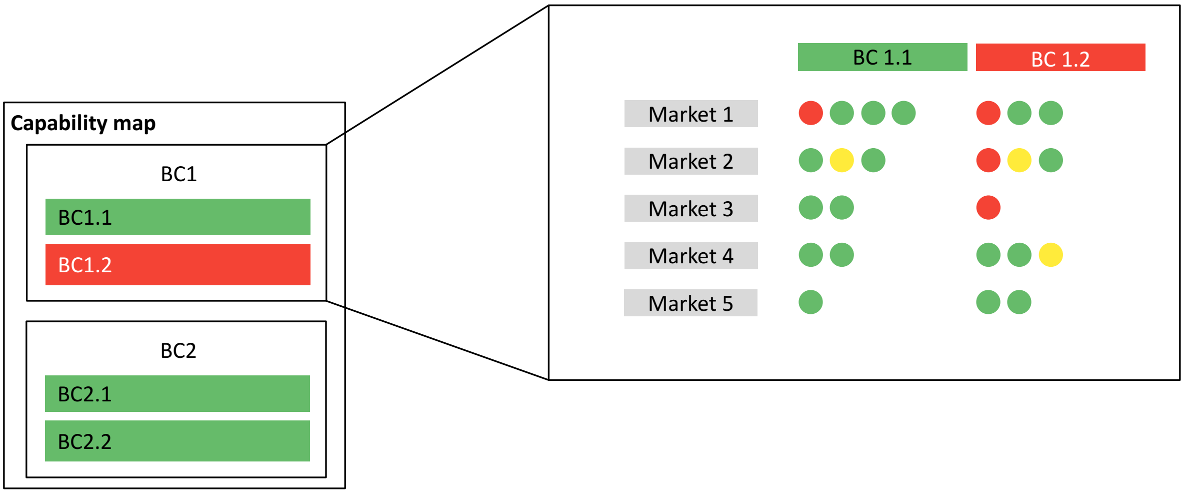

Figure 4.35.: Redesign of the drill-down view

In this example, the BCM consists of two L0 business capabilities (*BC1*, *BC2*) and each of them of two L1 business capabilities (*BC1.1*, *BC1.2* and *BC2.1*, *BC2.2*). BC1.1 is colored green (good condition) and BC 1.2 is colored red (poor condition). By clicking on BC1, the user will see a drill-down view into BC1. The user sees which application (bubbles) support which business capability (headers) in which market (rows). Depending on the visualization, a heat map is calculated for each application. The heat mapping of business capabilities depends on the heat maps of the supporting applications. If an application supports multiple business capabilities, the application is listed in each business capability column.

An alternative representation of applications is the use of rectangles. In this case, each application is illustrated by a single rectangle. If an application supports multiple business capabilities, the single rectangle is stretched over both business capabilities. After discussions with the experts of the case study partner, this representation format was rejected. With an increasing number of applications, this representation form becomes too confusing and would not provide any transparency rearding APC.

The color codes were defined in corporation with the case study partner. The involvement of the case study partner was crucial because the color coding depends on the size and maturity of the particular AP. Example for application lifecycle: consider an organization that operates 10,000 applications and where one L1 business capability is supported by approx. 50 applications. In this case, 10 applications over application lifecycle (in one business capability) indicate poor status of the business capability (Color coding rule: >10 application over application lifecycle = red). Using the same rule in an organization that operates only 800 applications in which one L1 business capability is supported by approx. 15 applications would be inappropriate: most likely no business capability would be colored red and the color coding should be adapted to the AP size. Tables 4.4, 4.5, 4.6, and 4.7 outline the specified color codes.

The application lifecycle visualization should illustrate to what extent business capabilities are supported by applications that already exceeded the lifecycle. The more supporting applications have exceeded a lifecycle, the more critical the business capability should be evaluated. The color coding at application level illustrates for how long an application has already exceeded the lifecycle. The longer the lifecycle is exceeded, the higher is the risk of security issues and the probability that changes and operating costs of an application are unnecessarily high.

	Application	**Business capability**
Green	End of lifecycle not reached yet	=0 supported applications pasted lifecycle
Yellow	lifecycle pasted >0 years	>0 supported applications pasted lifecycle
Red	lifecycle pasted >2 years	>2 supported applications pasted lifecycle

Table 4.4.: Color coding for application lifecycle visualization

It would be ideal if a business capability would be supported by exactly one application across all markets. In this case, there would be no redundancies in a business capability and, because of missing silo solutions, there would be no harmonization potential. However, silo solutions for specific markets are acceptable due to specific market requirements, but should be kept in a limited range. As discussed with the industry partner, the demand for a well-defined AP is that applications are used in as many markets as possible and the number of applications needed to support a business capability as few as possible. The color coding is based on the following hypothesis: the fewer markets that are supported by an application, the more critical the application should be rated. A business capability should be supported by a minimum number of applications. The higher the number of used applications, the more critical the business capability should be rated.

	Application	**Business capability**
Green	Application supports >4 markets	Supported by <=2 applications
Yellow	Application supports >1 markets	Supported by >2 applications
Red	Application supports =1 market	Supported by >5 applications

Table 4.5.: Color coding for harmonization potential visualization

The AP should be oriented to the structure of the BCM and dependencies between business capabilities should be kept to a minimum. Applications that support multiple business capabilities are not desirable since they increase the number of dependencies between business capabilities and lead to higher coupling. The hypothesis of this visualization is: the more business capabilities are supported by an application, the more critical the application should be rated. The more capability spanning applications that are used by a certain application, the more critical the business capability has to be rated.

	Application	**Business capability**
Green	Supports =1 business capability	Supported by =0 capability spanning applications
Yellow	Supports =2 business capabilities	Supported by >0 capability spanning applications
Red	Supports >2 business capabilities	Supported by >2 capability spanning applications

Table 4.6.: Color coding for capability spanning applications visualization

The case study partner aims to reduce the operation of applications in-house and transfer as many applications as possible into the cloud. When applications and all related maintenance activities are operated by a service provider, the number of applications in-house and the associated operating costs decrease. However, this hypothesis and visualization should be treated with caution: applications that support core capabilities (core applications) should be run in-house. Even if the operating costs of the AP decreases, service fees have to be paid to the provider. The color coding has the following logic: when an application is operated in the cloud, it is marked green, otherwise it is marked red. A yellow color is not defined on application level. The fewer applications of a business capability that are operated in a cloud, the more critically it is rated.

	Application	**Business capability**
Green	Operated in cloud	>60% supported applications operated in cloud
Yellow	–	>20% supported applications operated in cloud
Red	Not operated in cloud	<=20% supported applications operated in cloud

Table 4.7.: Color coding for cloud candidates visualization

The color coding is implemented in the source code of the software. Section 4.5.2.2 provides images and further explanations of the implemented visualizations.

4.5.2.2. Implemented software

Since the software is based on the solution of the first iteration, the technical conditions are the same: the software is a web application that has been programmed in AngularJS. Required AP data is extracted from a Microsoft Excel file. The colors and the design of the front-end aligns to the corporate design guidelines of the case study partner. Since only two parameters have to be selected (business unit and visualization), the starting dashboard has been removed. The AP data was extracted from the EA repository in August 2017 and illustrates the current AP.

Figure 4.36 illustrates the starting point of the software. The user sees a BCM (without color coding) and two drop-down menus: **(1)** selection of business unit (*FREQ–2)* and **(2)** selection of one out of four visualizations (*FREQ–3*). Both drop-down menus are mandatory (*NFREQ–5*). The Microsoft PowerPoint download button **(3)** is still implemented (*FREQ–1*). Since the software contains real data of the case study partner (*FREQ–5*), major parts of the screenshot have been blurred out (*NFREQ–2*).

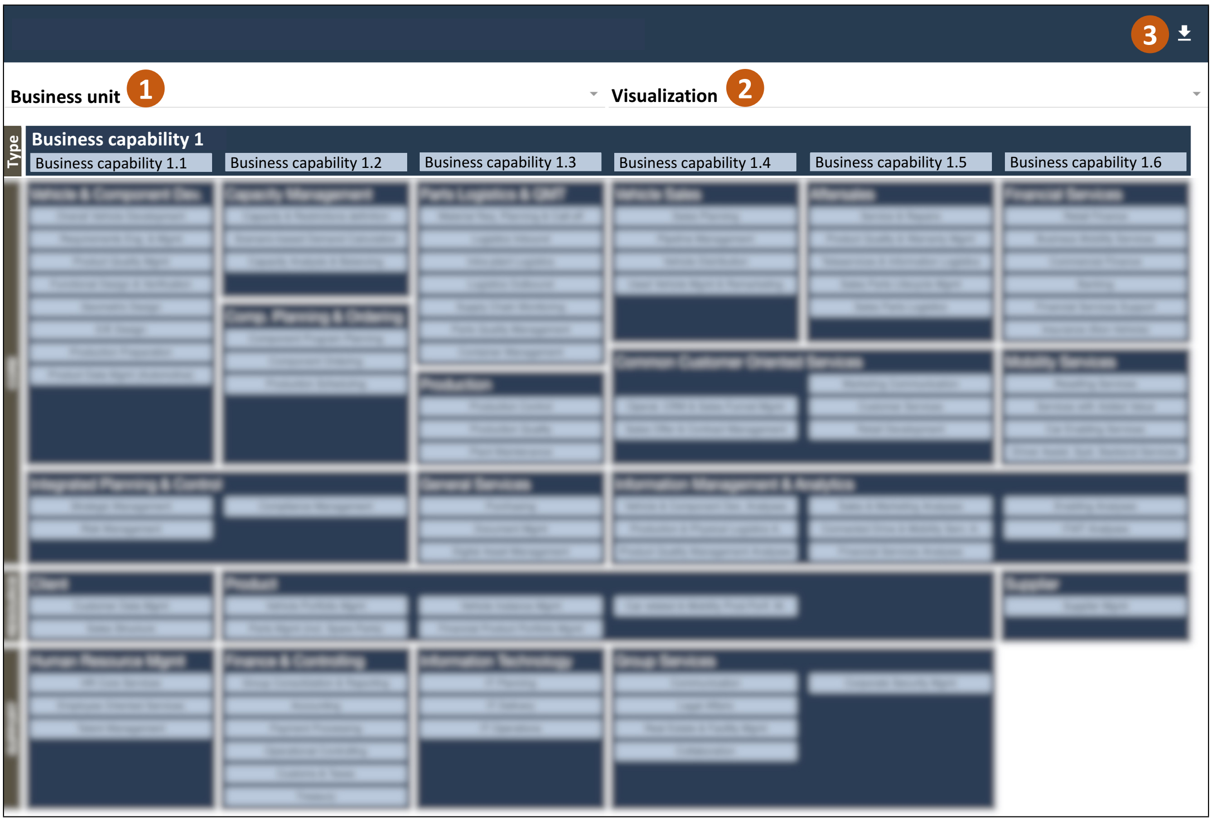

Figure 4.36.: Capability-based APC management with APC indicators: start view

When the user selects an organizational unit and a visualization, the software automatically calculates the corresponding heat map. Figure 4.37 shows what such a visualization looks like. The screenshot illustrates a heat map for the organizational unit *General serivce* and the visualization *Functional redundancy.* The selected parameters are displayed at the top of the visualization (*NFREQ–1*) The color coding considers only L1 business capabilities (*FREQ–7*). The financial service provider only uses selected business capabilities for its business. If no L1 business capability within a certain L0 business capability is supported by the AP, the entire cluster is not considered for the heat map. The heat mapping rules are explained in a legend below the visualization **(2)** (*FREQ–6*). Other information is not displayed within the visualization (*NFREQ–7*). The specified rules for the color coding are explained in Section 4.5.2.1 (*FREQ–8,9,19*). If the user changes a parameter (other organizational unit or visualization), the heat map is recalculated automatically (*NFREQ–3*). All other visualizations align to this design (*NFREQ–4*). Therefore, it is not necessary to also outline the other three implemented visualizations.

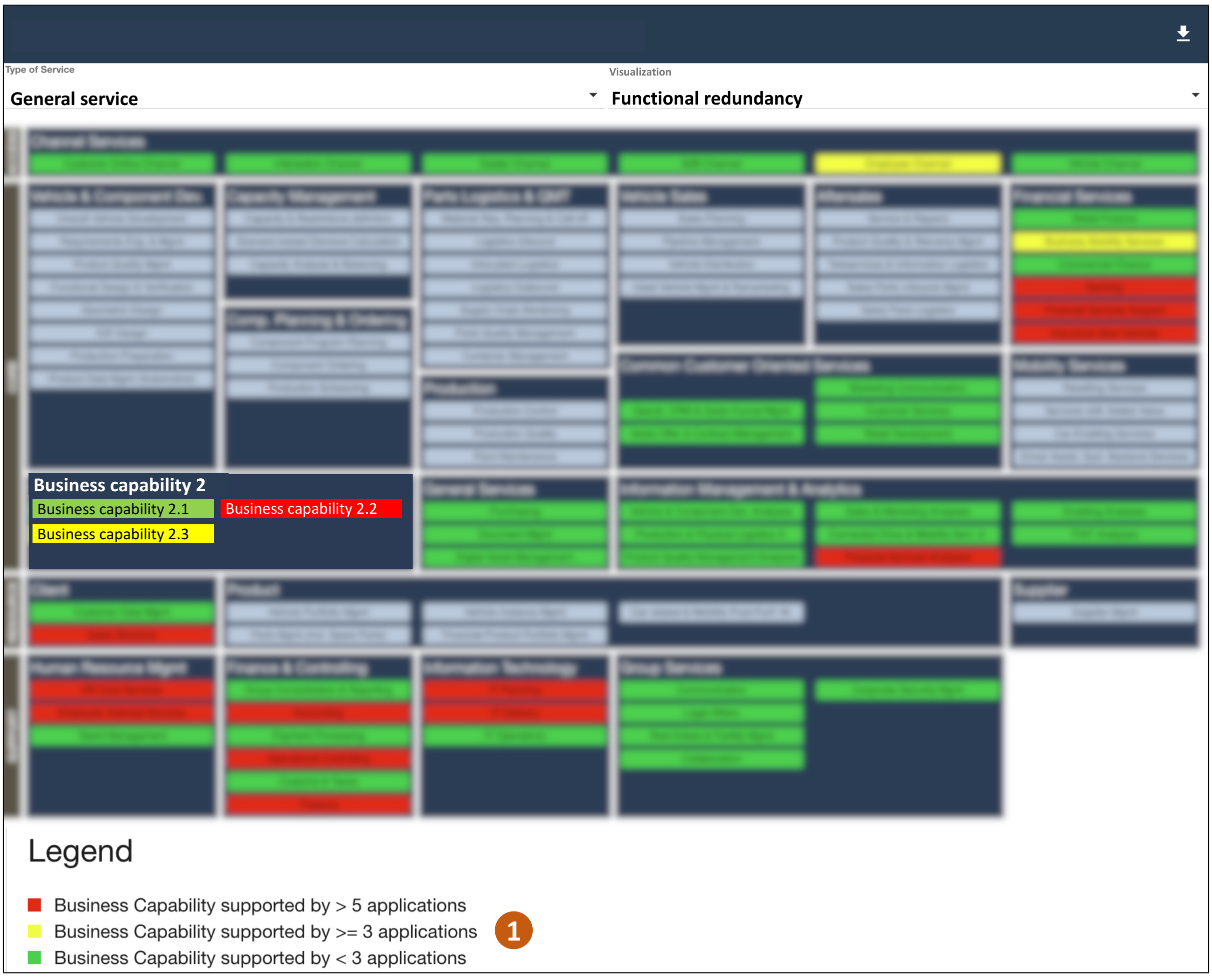

Figure 4.37.: Capability-based APC management with APC driver: BCM heat map

In Figure 4.37 *Business capability 2* consists of three L1 business capabilities, colored red, blue, and green. By clicking on the L0 business capability, the user gets the drill-down view (*FREQ–4*). Figure 4.38 shows the drill-down for business capability 2.

The L1 business capabilities are displayed at the bottom (column) and the markets on the left side (rows). The position of the applications (bubbles) indicates which application is used to support a business capability in a specific market (cells). The legend at the botton of the visualization is now divided into one legend for the business capabilities and a second for the applications. The button in the upper left corner **(1)** exits the drill-down view. Depending on the sum of the used applications, the visualization can get lengthy in the vertical. A Microsoft PowerPoint export is not possible and has not been considered for the drill-down view.

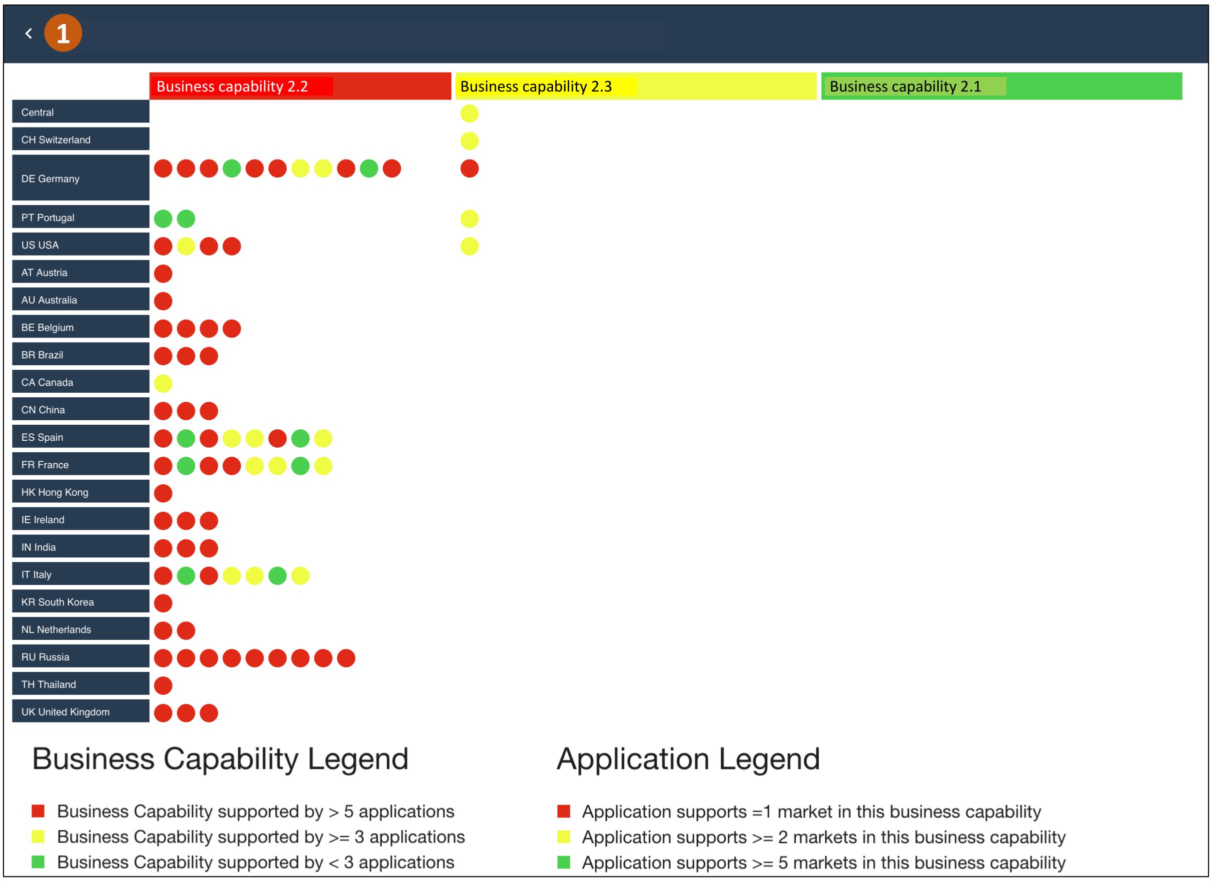

Figure 4.38.: Capability-based APC management with APC driver: BCM heat map

As previously discussed, applications are listed multiple times in this visualization format: if an application is used in different markets or business capabilities, it is listed in each cell. To provide more transparency about the current state of the AP, the software provides a highlight function. If the user hovers over an application, the name of the application is displayed in a window. When the user clicks on an application, all cells that illustrate the same application are highlighted with a border. Figure 4.39 shows an example of this function. *Application 1* is used in the market *DE Germany* to support *Business capability 2.2* The application is colored yellow. Consequently, this application is used in 2 to 4 markets. By clicking on the application, the user can see that the application is also used in the markets *ES Spain*, *FR France* and *IT Italy*. To end the highlighting, the user has to click on one of the highlighted applications. The user can highlight several redundancies simultaneously.

The function is available for all implemented visualization, although the functional redundancy and capability spanning application visualizations primarily benefit from it. In both visualizations it is crucial to illustrate which business capabilities or markets use a specific application.

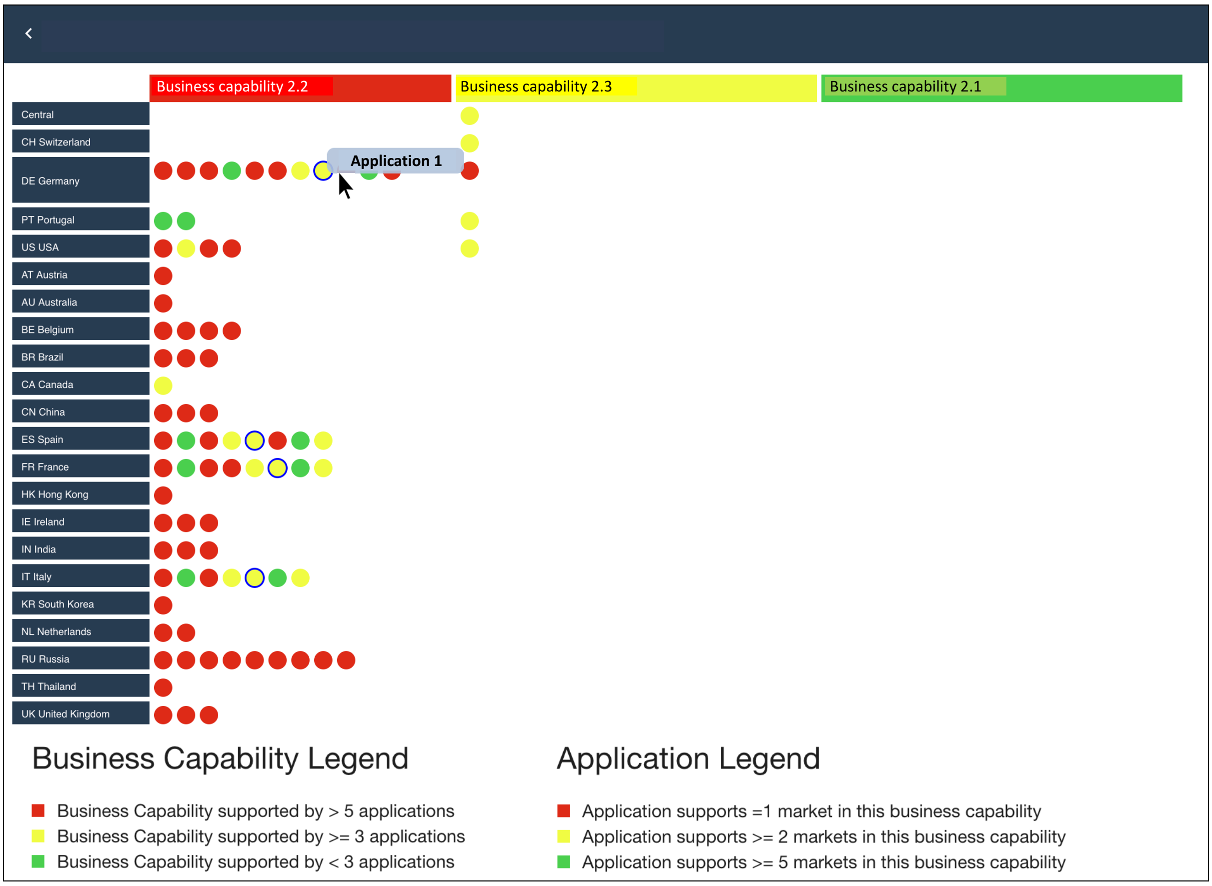

Figure 4.39.: Capability-based APC management with APC driver: highlight applications

The majority of the functional and non-functional requirements were fulfilled with the implementation (reference to the requirements in the explanation of the screenshots). The benefit of the visualizations was evaluated by conducting expert interviews. The evaluation approach and the results are illustrated in Section 4.5.3.

4.5.3. Evaluation by expert interviews

A crucial point of criticism in the first iteration was the use of KPIs. They are difficult to understand and are not ideal to provide transparency regarding APC. The definition of actions to decrease APC is difficult with this approach. The use of the BCM as a visualization format was considered as helpful. Hence, the evaluation mainly focuses to:

- assess to what extent the visualizations provide transparency about APC,
- identify architectural actions that can be derived using the visualizations, and
- investigate the readability and understanding of the drill-down view

The starting point of this evaluation was identical to that of the first iteration: there was no empirical data that already assessed these types of visualizations and it was unclear which part of the visualizations should be discussed in-depth. Consequently, the visualizations were evaluated by conducting semi-structured interviews. All experts have several years of experience in EAM and are familiar with the BCM concept. Since the software contains company-related information, only experts from the automotive company were interviewed. One interview was conducted via video call, the others in person. Table 4.8 presents an overview of the participants. Each interview took approx. 30 minutes.

Participant	**Position**	**Experience (years)**
#1	Enterprise architect	10
#2	Head of EAM	5
#3	Enterprise architect	12
#4	Enterprise architect	5
#5	Enterprise architect	5
#6	Enterprise architect	20
#7	Head of big data	3
#8	Enterprise architect	5
#9	Enterprise architect	8
#10	Enterprise architect	5
#11	Business architect	8
#12	IT strategy specialist	0
#13	Enterprise architect	8

Table 4.8.: Overview of interviewed experts

The evaluation was conducted using a questionnaire, which can be divided into four parts: 1) general questions about the role and person of the interviewee, 2) questions about the readability of the BCM heat mapping and drill-down view in general, 3) benefits of each visualization, and 4) recommended next steps. The questionnaire considers both standardized answer options (drill-down) and free comment fields. The questionnaire is illustrated in Appendix A4.

After a short introduction to the research project, the software was shown to the participants. Explained was, how to generate a heat map, how to read the heat map on a BCM level, and how the drill-down view is structured. Every visualization was explained individually. Comprehensive questions were discussed during this presentation. After the presentation, the questionnaire was filled out with the participants.

The expert interviews were analyzed by conducting qualitative content analysis [Ma02]. The context of each response in each documented questionnaire was interpreted, structured, and aggregated to gather insights about the following topics: general idea and software, visualization application lifecycle, harmonization potential, capability spanning applications, and cloud candidates. The results of the analysis are illustrated in upcoming Sections 4.5.3.1, 4.5.3.2, 4.5.3.3, 4.5.3.4, and 4.5.3.5.

4.5.3.1. General idea and tool

Figure 4.40 illustrates to which extent the software can be used to increase transparency about APC and derive suitable actions. Each bar illustrates a specific benefit from the experts. The length of the bars shows how many experts mentioned the respective benefit. The identified APC indicators in this thesis (cf Table 2.5) are illustrated at the bottom of the chart. By mapping the APC indicators to the specific benefits, it can be concluded to which extent the software contributes to provide transparency about APC. The mapping was discussed with an EA expert of the case study partner.

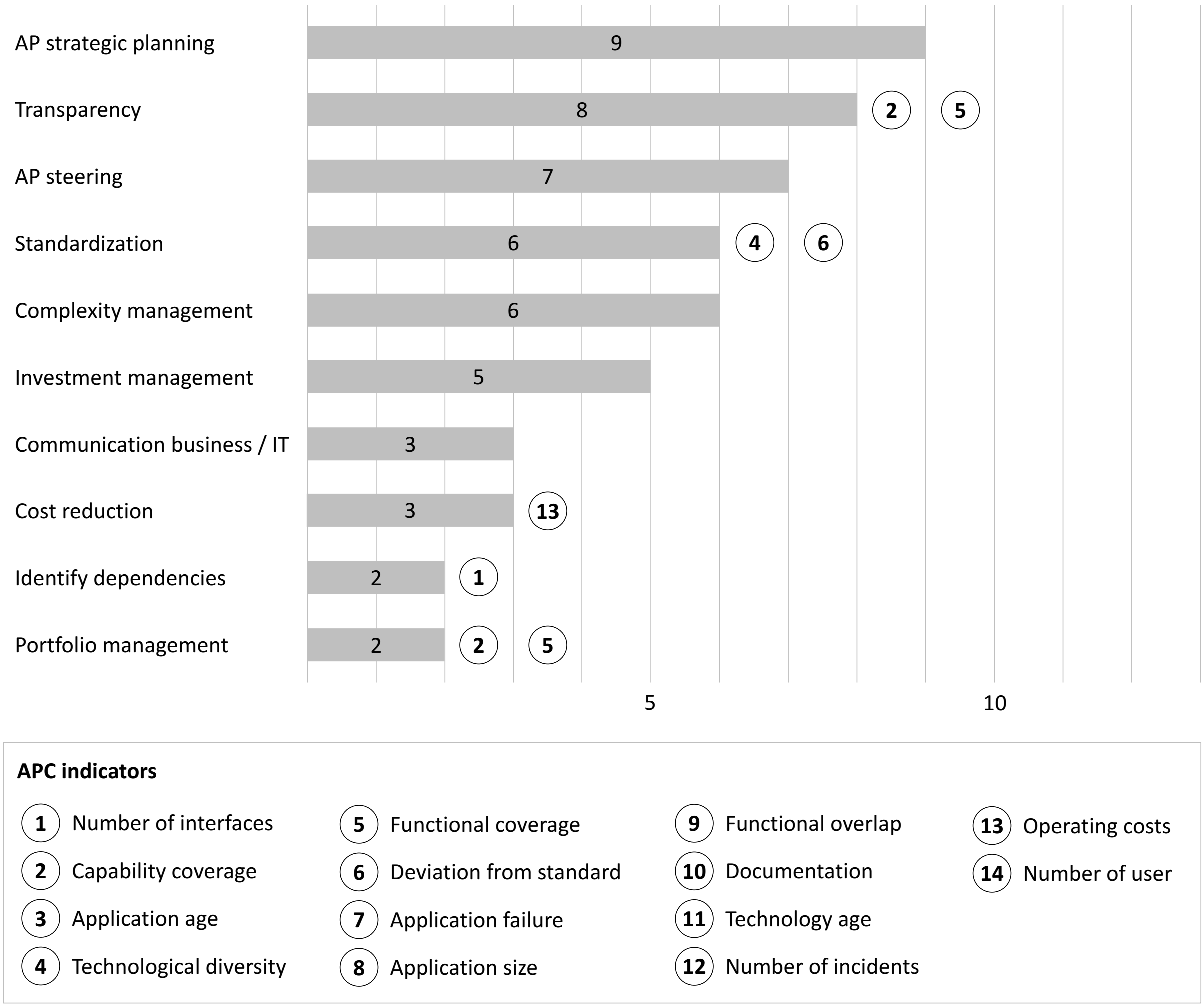

Figure 4.40.: Mentioned benefits of software solution for APC management in general

The mapping of applications to business capabilities and markets helps to derive transparency about the current AP. The compact view helps to identify applications that cover too many business capabilities or which are unnecessary silo solutions (*Transparency, Portfolio management*). Applications that do not comply with the architectural standards (*Standardization*) can be identified quickly. Applications that cover too many business capabilities indicate unnecessary dependencies (*Identify dependencies*). The identification of candidates for removal helps to decrease the operating costs (*cost reduction*). *Complexity* and *Investment management* have been mentioned several times and can likely be mapped to most of the APC indicators, but are too general for an unambiguous map.

Six experts emphasized the clarity and intuitiveness of the approach for APC management. However, the experts also stated some criticism: four out of ten experts mentioned that the drill-down should go one level deeper (L2 business capabilities). This would allow a more accurate identification of misalignments that contribute to certain APC indicators. Due to missing data, such mapping and implementation was not possible.

4.5.3.2. Visualization application lifecycle

Each interviewee was asked to rate each visualization in terms of increasing APC transparency (likert scale: very high =1,...very low =4). This visualization was mostly deemed as beneficial. Three experts rated it with very high and seven with high. Three experts rated the visualization as low. They criticize that uniformed weights for all applications might be inaccurate. Certain applications may be deliberately used in the extended lifecycle due to missing alternatives. Figure 4.41 outlines the benefits of the visualization.

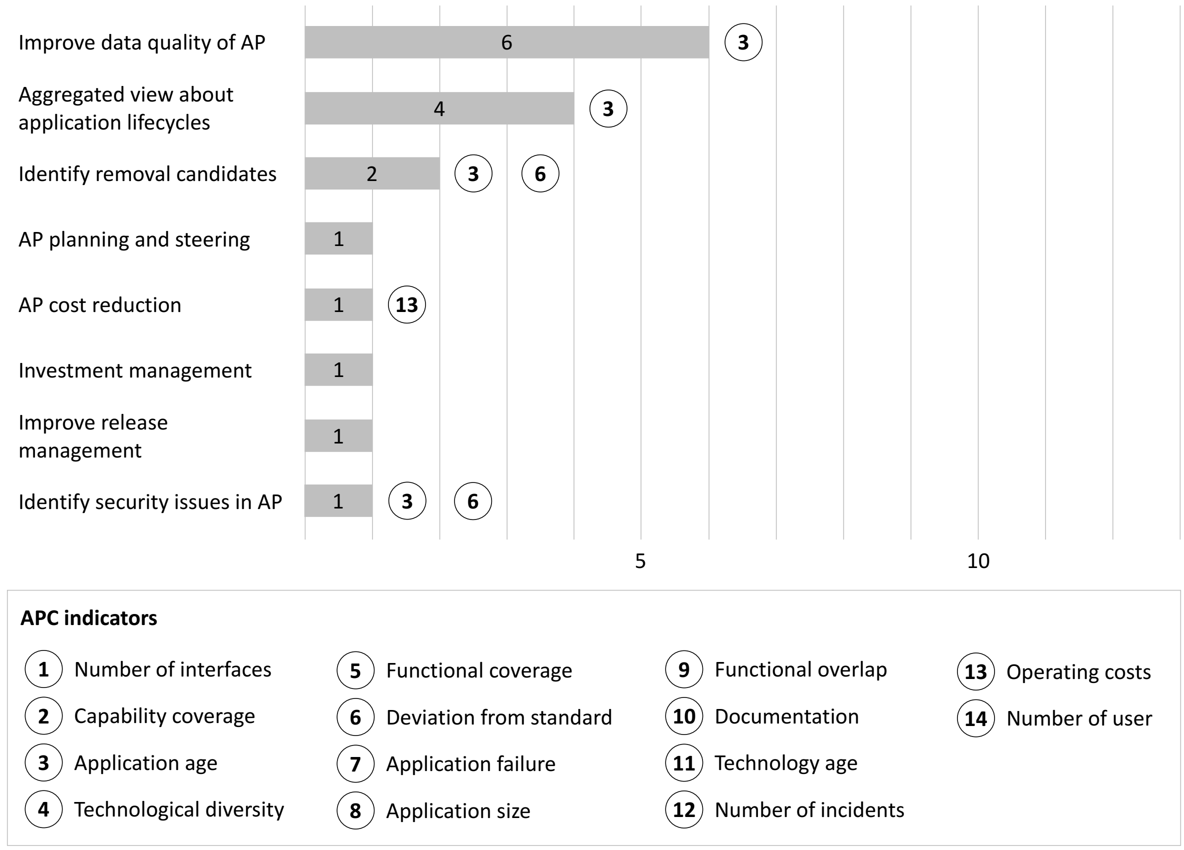

Figure 4.41.: Mentioned benefits of visualization application lifecycle

The visualization helps identify applications that lead to increased APC due to their lifecycle. In this case study, many applications were identified that have not entered a lifecycle at all. The capability-based view helps to identify whether this is the case within strategically important business capabilities (*Improve data quality of AP*). It also helps to identify candidates which should be removed due to their extended lifecycle (*Identify removal candidates*). This plays an important role in strategically important business capabilities, as technical risks can have a greater impact here (*Identify security issues in AP*). Applications that have exceeded their lifeycle may lead to higher operation costs. This view helps to increase transparency about these cost drivers (*AP cost reduction*).

4.5.3.3. Visualization harmonization potential

Visualizing harmonization potentials in the AP attracts much more attention: Seven experts rated the benefit as very high; five as high, and one as low. The one expert criticized that a drill-down to L2 business capabilities would be crucial. As previously mentioned, such a drill-down was not possible due to missing data.

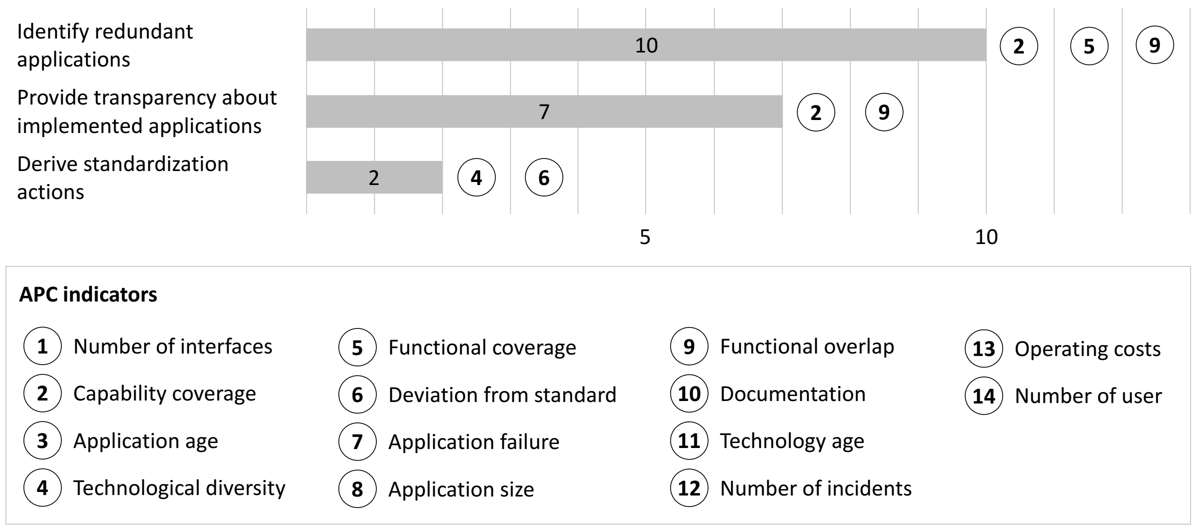

Figure 4.42.: Mentioned benefits of capability spanning visualization

The drill-down view was seen as very helpful. The view is well designed, and in combination with the color coding and highlight function, the visualization *provides transparency about implemented applications*. The consideration of the markets helps to derive more appropriate actions.

10 experts mentioned that the visualization helps to identify redundant applications. The drill-down view shows whether unnecessary silo solutions are operated and whether some business capabilities are supported by too many applications. Silo solutions do not meet the standard of the organization. Corresponding breaches can be detected quickly.

4.5.3.4. Visualization capability spanning applications

This visualization was also considered beneficial by the majority of experts: six experts rated the benefit as very high, three as high, and three as low. One expert did not provide any rating. The experts criticized that a uniform assessment of all applications regarding their number of business capabilities may be inaccurate. Some applications support multiple business capabilities, which makes sense from an architectural point-of-view.

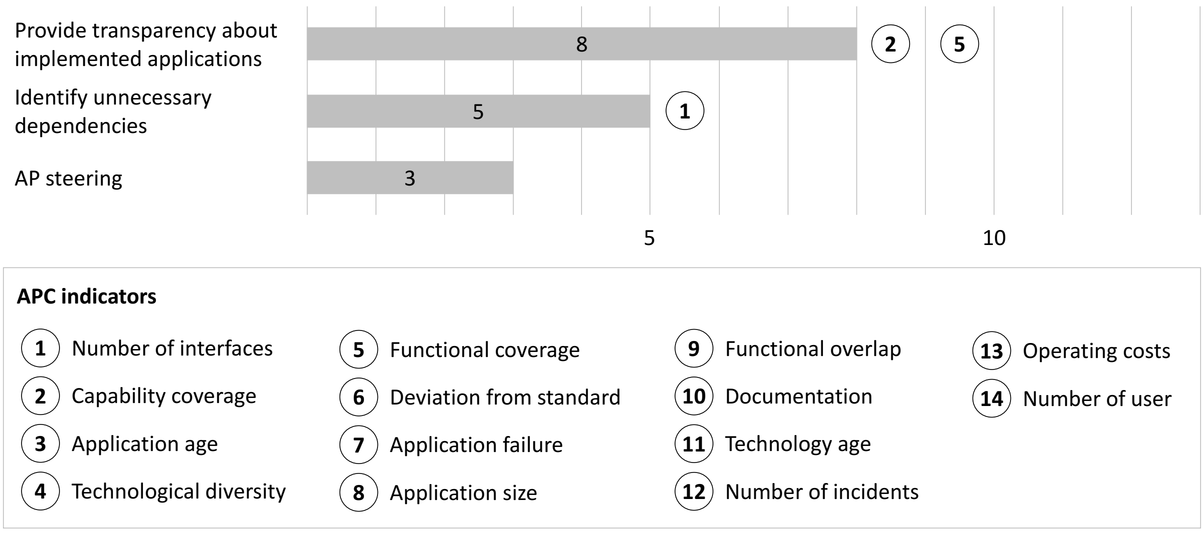

Figure 4.43.: Mentioned benefits of visualization capability spanning applications

However, eight experts mentioned that this visualization *provides transparency about implemented applications*. They are able to identify applications that support too many business capabilities and those which should be split into multiple applications to increase agility. Since the drill-down view highlights applications that support multiple business capabilities, the experts were able to *identify unnecessary dependencies* between business capabilities.

4.5.3.5. Visualization cloud candidates

The visualization of cloud candidates to increase the transparency of APC was highly doubted by the experts. Two experts rated the visualization as very high, five as high, two as low, and two as very low. Two experts did not provide any rating. The organization did not evaluate to what extent cloud solutions should replace in-house applications and is still working on a strategic standard regarding this topic. However, the experts agreed that this decision had to be done case-by-case. The decision depends on the strategic relevance of the business capability to be supported, the technical need of the organization to an application, the criticality of the proceeded data within an application, and various other individual factors.

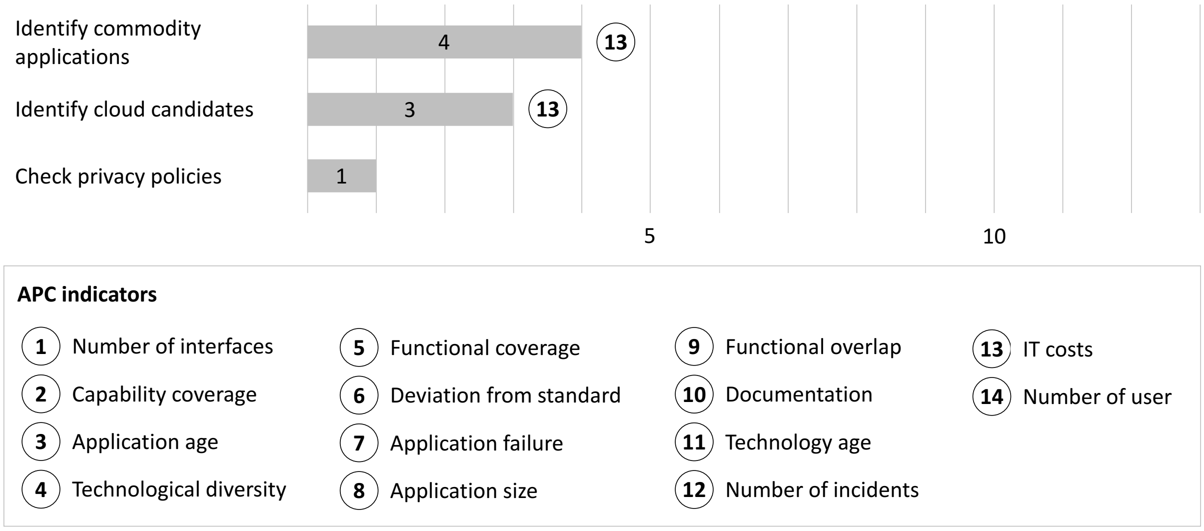

Figure 4.44.: Mentioned benefits of visualization cloud candidates

However, three experts mentioned that the visualization may help to *identify cloud candidates*. The BCM does not only consist of business-critical capabilities. Commodity business capabilities (e.g human resources), which indicate by their color coding that many supporting applications are still operated in-house, can be investigated concerning cloud migrations.

4.5.4. Discussion of findings

The objective of the evaluation was to assess whether the presented visualizations provide transparency about APC indicators and support the deduction of suitable actions. The experts explained which actions can be derived from the visualizations. These were mapped to dedicated APC indicators. The map was discussed with an expert from the case study partner.

During the initial definition of the visualizations (cf. Section 4.3) it was considered that each visualization increases the transparency of dedicated APC indicators (cf. Table 4.2). In order to evaluate whether the visualizations fulfill their purpose, the results of the evaluation were compared with the corresponding objectives of each visualization (increase transparency about dedicated APC indicators).

Table 4.9 summarizes which APC indicator could be addressed with each visualization. The columns illustrate the APC indicators. The numbering corresponds to the applied numbering for the APC indicators in Figures 4.40, 4.41, 4.42, 4.43, and 4.44. If a visualization provides transparency to the corresponding APC indicator, the relevant cell is marked with an *X*.

A comparison of the requirements (cf. Table 4.2) and the results (cf. Table 4.9) shows that APC indicators that should be addressed are also considered by the particular visualizations. The results show that the visualizations consider even more APC indicators. The visualization *Harmonization potential* addresses the highest number of APC indicators. The drill-down view shows which applications are used to support specific business capabilities on a single view and

	APC indicators													
Visualization	**01**	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**09**	**10**	**11**	**12**	**13**	**14**
Application lifecycle			X			X							X	
Harmonization potential		X		X	X	X			X					
Capability spanning appl.	X	X			X									
Cloud candidates													X	

Table 4.9.: Overview of interviewed experts

helps to identify redundant applications, functional overlaps, and architectural misalignments. A pattern can not be identified from the results. The implementation and evaluation of all visualizations would possibly allow the identification of certain patterns.

It was explicitly refused to ask whether the visualizations provide transparency to particular APC indicators. There was the risk that certain APC indicators (such as IT costs or capability coverage) are indirectly addressed through all visualizations, leading the expert's responses to a biased result. At the same time, the qualitative research approach has its limitations: the mapping of the mentioned benefits to the APC indicators has been done qualitatively. In order to increase the reliability of the results, a more extensive (e.g. more expert interviews or further discussions of the mappings) would be necessary.

However, it can be said that the second iteration has served its purpose.

- Significant feedback from the first iteration was that the KPIs are too difficult to understand. The evaluation of both the concept and the implemented prototype shows that the content of the visualizations is more understandable and allows to draw conclusions regarding APC.
- The use of BCM as a visualization medium was considered reasonable in both the first and second iterations. The drill-down view in particular, (and it's highlighting function in the second iteration) was considered to be very useful.
- In both iterations, the design of the software solution was received very positively and is intuitive, easy to use and provides transparency about APC.

CHAPTER 5

Conclusion

This chapter gives a summary of the gathered research results of this thesis. Section 5.1 summarizes all conducted research steps and results, and discusses the research hypothesis and RQs. Section 5.2 outlines the limitations and Section 5.3 presents an outlook for further research.

5.1. Summary

This thesis investigates how to provide transparency about APC. The research hypothesis is that the BCM concept can be used as a visualization medium to increase transparency about APC. In order to investigate this research hypothesis, three RQs have been defined which (RQ1) examine how the concept of a capability-based APC can be defined, (RQ2) which APC indicators are relevant, and (RQ3) how a suitable software solution should be designed (cf. Section 1.1). Since the thesis aims to produce and evaluate certain artifacts, the adopted research design aligns to the design-science approach by Hevner et al. ([HM04]). The targeted contributions are explained in Section 1.2 and adopted research design is presented in Section 1.3.

Chapter 2 introduces the foundations and related work of this thesis. Since application architecture (technical representation of an AP) reflects a certain layer of an EA, the thesis can be assigned to the EAM research. Section 2.1 introduces to foundations of EA and EAM, outlines its purpose, fundamental layers and its core principles. Section 2.2 explaines significant constructs of the application architecture layer (definition of application, AP, and APM). Since the thesis aims to investigate if the BCM concept can be used to increase the transparency about APC, Section 2.2 defines the term APC. Section 2.3 illustrates the third block of the foundations and explains the business capability and BCM concepts. Section 2.4 discusses related work to this thesis: the section presents contributions related to complexity management in EAM and APM and investigates to which extent introduced APM methodologies already address APC transparency purposes. Based on the foundations and related work, Section 2.5 positions the contribution of this thesis in research.

The definition and evaluation of the artifacts was done in two iterations. Chapter 3 documents the approach and results of the first iteration: the objective was to measure APC with three KPIs and visualize the results on a BCM. Section 3.1 introduces the concept. Section 3.2 explains which KPIs have been defined, how they are structured, which information is required for each KPI and how the results should be interpreted. The definition of the KPIs was conducted in close cooperation with two experts from an automotive company. The evaluation of these KPIs was carried out in a case study. The case study used real data from the same automotive company and considers a) the calculation of the KPIs b) their representation of the original BCM, and c) the implementation of a suitable software solution (prototype). The implementation and evaluation of the case study is explained in Section 3.3. Although the capability-based approach and its respective implementation in the software solution were considered as useful, the representation of APC with KPIs was considered as unsuitable. The lessons learned are explained in Section 3.4.

The feedback of the first iteration was used to redesign and evaluate the concept in a second iteration. The structure and results of the second iteration are illustrated in Chapter 4. The most significant change was the removal of the KPIs and the definition of capability-based visualizations, each of them designed to provide transparency about certain APC indicators. Furthermore, the software solution has been adapted according to the new requirements. The redesigned concept is explained in Section 4.1. Overall, 14 visualizations have been defined. The definition was carried out in close cooperation with two EA experts from two different organizations. The visualization identification process is outlined in Section 4.2. Each visualization is presented in Section 4.3 In order to investigate the benefit and feasibility of each visualization, experts from 25 organizations have been interviewed. The results show that some visualizations are considered to be particularly beneficial. The results of the qualitative study are documented in Section 4.4. Based on gathered insights from the practitioners and group discussions with EA experts from the automotive company (same organization from the first iteration), four visualizations were implemented and evaluated by conducting a case study with real data from the automotive company. The structure and results of the case study are documented in Section 4.5. It turned out that practitioners consider the redesigned visualizations to be more understandable. In particular, the redesigned drill-down view helps increase the transparency about specific APC indicators.

At the beginning of the thesis, a research hypothesis and three RQs were defined. On the basis of the gained insights, these are answered in the following paragraphs:

> ***RQ 1:*** How is the conceptual design of capability-based APC management defined?

The concept requires that the relevant applications are mapped to the business capabilities. The concept pursues a three-tier architecture: the BCM serves as a visualization medium (*presentation layer*). The visualization mechanisms and rules – in this case color coding of business capabilities – are stored in the *logic layer*. The required information of the application is stored on the data layer. Depending on the desired evaluation, the required information is extracted from the data layer, processed in the logic layer and the result visualized on the presentation layer.

Table 2.5 illustrates the identified APC indicators in research. Although our research group reveals further APC indicators [AB16a], the identified indicators from related work are more suitable for a capability-based APC management purpose, since they are measurable and originate from architectural nature. The considered measures have to be measurable and mappable to dedicated business capabilities. Organizational APC indicators (e.g. interlocking between organizational units or unsuitable release management process) can not be considered. Almost all identified APC indicators were considered within the defined visualizations (cf. Table 4.2).

> ***RQ 2:*** What are suitable visualizations for capability-based APC management?

The findings revealed that the use of specific visualizations to address dedicated APC indicators is more useful. The definition of KPIs to illustrate APC from different viewpoints is too confusing and vague and respective color coding on a BCM is not transparent enough to derive actions of APC reduction. A drill-down view into certain business capabilities helps to investigate misalignments within the business capability considering the implemented applications. An overview and assessment of the defined and evaluated visualizations is provided in Section 4.3, 4.4, and 4.5.3.

All defined visualizations make use of the same color coding: red= poor, yellow= medium, and green= good condition. Although more granular color codes are possible, the interviews revealed that practitioners prefer this lightweight definition.

> ***RQ 3:*** How can a software solution support the enhancement of APC transparency using a BCM?

The implemented software relies on collected requirements from practitioners. The evaluation shows that the interviewed experts were satisfied with the design and setup of the software and did not have any criticism from a design point of view. The use of the original BCM (design) has high recognition value and enables practitioners to quickly find their way within the front-end.

The interviews have shown that a software solution helps to create transparency about APC indicators. A productive software solution – connected to the relevant EA repositories – enables real-time evaluations. The drill-down and highlighting functionality was considered as particularly helpful.

> ***Research hypothesis:*** The BCM can be used to increase transparency about APC indicators.

Based on the results and the answered research questions, it can be concluded that BCM supports APC management practices. The BCM can be used as a visualization medium. It offers the advantage of considering business/IT alignment purposes. All APC indicators that can be mapped to applications or to business capabilities can be addressed through the BCM. The color coding can be defined individually and can be realized in different ways.

Considering the defined contributions in Table 3.1, all targeted contributions were achieved. Table 5.1 gives an overview of the contributions and a reference to the respective sections in which the contents are presented.

ID	**Contribution**	**Section**
#C1	Concept for capability-based APC management	Section 3.1 Section 4.1
#C2	KPIs for capability-based APC management	Section 3.2
#C3	Visualizations for capability-based APC management	Section 3.3.2.3 Section 4.3
#C4	Software solution for capability-based APC management	Section 3.3.2.3 Section 4.5.2.2

Table 5.1.: Recapturing of contributions

To summarize, this thesis provides conceptual and technical best practices for the implementation of capability-based APC management. The conceptual design, KPIs, APC indicator driven visualizations, and the software solution are the artifacts of this thesis.

Although all contributions rely on scientific approaches and the artifacts are evaluated appropriately, there are some limitations that should be named and are outlined in Section 5.2.

5.2. Limitations

During the entire research process it was ensured that all decisions and conclusions were based on scientifically elaborated facts: before the artifacts were produced and evaluated a comprehensive literature research was conducted. All defined requirements consider best practices of research and requirements of practitioners. However, the produced artifacts and the research design met some limitations, which are outlined in the following sections.

5.2.1. Limitations of concept for capability-based APC management

The concept is explained in Section 3.1 (Section 4.1 after redesign). The explanation is limited to the core structure of the concept: it describes which layers should be considered for capability-based APC management, how they are related to each other and which information or tasks are assigned to each layer. A detailed definition of roles, responsibilities, reference models per layer etc. is not given and would increase the maturity of the concept. A technical documentation of the concept (e. g. definition of APIs) would facilitate the implementation in organizations and would clarify which information is needed and in which format.

5.2.2. Limitations of KPIs

The definition of the KPIs relies on best practices from research (cf. Section 3.2: the process considers requirements/characteristics of well-defined KPIs [Pa15] and follows the presented development process of Jolland et al. [JL03].

The design of the KPIs considers weights for the individual APC indicators. The weights relies on subjective assessments of the participating EA experts. However, related work [AB16, Mo09a] has shown that the effect of APC indicators between each other can be quantified. These insights have not been considered. The weights relies on the assessment of two experts from the same organization, which reduces the objectivity of the KPIs. In order to increase the robustness of the KPIs, it would be necessary to consider weights of more experts from different organizations and to include identified dependencies between the APC indicators from research.

Generally speaking, the evaluation shows that the significance of the KPIs is doubtful: the term complexity is defined as very fragmented in IS research (cf. Section 2.2). The defined KPIs consider several APC indicators in their definition and as outlined in the evaluation, (cf. Section 3.3.3) experts had serious issues in interpreting the KPIs and their results. In order to increase the significance of the KPIs, the APC indicators should be reassessed. In addition to that, it should be defined how the results of the KPIs are to be interpreted and which concrete measures can be derived by the calculations.

5.2.3. Limitations of visualizations

The initial definition of the visualizations was performed in cooperation with two experts from two different organizations. Although the definition of the visualizations considers insights from literature and the input from practitioners, there is a risk that useful visualizations have not been defined. In order to increase the robustness of the provided visualizations, more experts from different companies should have been involved during the definition phase.

The conceptual definition of the color coding is presented exemplary. Although the thresholds depend on organization-specific conditions (size of organization, maturity of the application architecture), it would have been useful to develop best practices or guidelines to determine these thresholds.

To evaluate the usefulness of the visualizations, 25 organizations were interviewed. All experts were asked to rate the benefit and feasibility of each visualization (cf. Section 4.4). The results are summarized in Figure 4.32 and reveal that five visualizations have a rather low benefit/feasibility rating. This result shows that some defined visualizations are not suitable for practical use.

The visualization focuses on technical and measurable APC indicators. Organizational APC indicators [AB16a] are not considered by the visualization.

5.2.4. Limitations of software solution

The developed software is a prototype. Although all functional and non-functional requirements have been considered, the implementation is not yet ready for production. The BCM and the data were implemented directly into the source code. It is not possible to add further data, make changes to the BCM, etc. Concerning technical limitations, especially Section 3.3.2.1 should be recaptured: related work by Roth [Ro14], Reschenhofer [Re17] and other authors [KB10, Mo09, SM12, TS13, RR14] outline requirements for EA visualizations pipelines regarding users, responsibilities and models per abstraction layer. In order to ensure the scalability and maintainability of the software, it is important to consider these requirements. Since these requirements were not considered in the implementation, the software meets some serious limitations from a technical standpoint.

The drill-down functionality is limited to L1 business capabilities. Many experts stated that a drill-down to L2 business capabilities is necessary to derive actions. Due to missing data, this was not possible and this function was not implemented in the software.

5.2.5. Limitations of evaluation

The evaluation of the artifacts mostly relies on qualitative research results. The KPIs of the first iteration, the visualizations of the second iteration and the software solution were evaluated by expert interviews. The approach of qualitative content analysis is based on the subjective assessment of the researcher and a lack of objectivity is a common criticism [RW16]. In order to increase the robustness of the artifacts, the consideration of quantitative methods should still be considered.

The research design is characterized by close cooperation with practitioners: The KPIs were defined and evaluated in collaboration with two experts from an automotive company. The benefit of the visualizations from the second iteration were evaluated with experts from 25 different organizations and both approaches were evaluated by two case studies, each of them considering real data from practitioners. One automotive company was very involved in this research: the AP data and the BCM of both case studies refer to data from this organization. The company was heavily involved in defining the KPIs of the first iteration and the visualization of the second iteration. The strong involvement of an organization entails the risk that the research results are too strongly tailored to a specific organization and the generalization of the results can be criticized.

The evaluation of the redesigned approach only considers four out of 14 defined visualizations. In order to increase the relevance of the evaluation, a complete evaluation with all visualizations would be necessary.

5.3. Outlook

This thesis provides valuable contributions for APC management but also reveals new research opportunities for the EAM and APC management community. The following sections give a brief outline of topics that are worthwhile for further investigation. Although this thesis deals with manifold EAM topics (APC, BCMs, EA visualizations), the highlighted opportunities aligns to the domain of this thesis (using BCM for APC management).

5.3.1. Clarify the definition of APC

Section 2.4.2 gives an overview of how the research community defines APC. Looking back, it can be said that the term is defined fragmented: This thesis defines that technical or organizational circumstances lead to APC (APC driver). The consequences of these drivers manifest themselves in APC effects. Other researchers investigate the term from different viewpoints (e.g. notions of complexity by Schneider et al. [SZ14] or conceptual Model by Mocker [Mo09a]).

Table 2.5 gives a comprehensive overview of identified APC drivers and effects from research. However, it can be concluded that the term needs further shape. Research investigates the term from different perspectives, identifies manifold root causes of APC but did not provide a comprehensive and aligned definition of the term. Further research should investigate the role of single APC drivers and effects and how they relate to each other.

5.3.2. Increase transparency about organizational APC indicators

As already outlined above, the KPIs of the first and the visualizations of the second iteration only consider technical / application oriented APC indicators. However, our research group identified plenty of organizational-driven APC indicators, which are not considered in the developed artifacts. Further research should investigate how to increase transparency about organizational APC indicators and how they relate to each other.

5.3.3. Refine thresholds for color coding

All developed visualizations make use of color coding to indicate the status of particular business capabilities from different viewpoints. Section 4.3 illustrates the identified visualizations and outlines that the color coding of the visualizations depends on the AP maturity and size of thew organization. Consequently, the used color coding in Section 4.3 is illustrative. The color coding, within the case study of the second iteration was defined with experts from the automotive company. Although the color coding depends on the maturity and size of the organization's AP, further research might investigate patterns or best practices for the color coding definition by examining dependencies between AP maturity, size, and suitable color coding.

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Abbreviations

AP Application portfolio

APC Application portfolio complexity

APM Application portfolio management

approx. Approximately

ARIS Architecture of Integrated Information Systems

avg. Average

BCM Business Capability Map

EA Enterprise Architecture

EAM Enterprise Architecture Management

IaaS Infrastructure as a Service

IT Information technology

KPI Key performance indicator

PaaS Platfrom as a Service

RQ Research question

vs. versus

APPENDIX A

Appendix

A1. APC correlations

```
*----------------*
*   COMPLEXITY   *
*----------------*

Call:corr.test(x = comp[1:4])
Correlation matrix
      int   cov   age  tech
int  1.00  0.33  0.10  0.49
cov  0.33  1.00 -0.19  0.33
age  0.10 -0.19  1.00 -0.05
tech 0.49  0.33 -0.05  1.00
Sample Size
[1] 26
Probability values (Entries above the diagonal are adjusted for
multiple tests.)
      int  cov age tech
int  0.00 0.50 1.0 0.07
cov  0.10 0.00 1.0 0.50
age  0.62 0.36 0.0 1.00
tech 0.01 0.10 0.8 0.00

 To see confidence intervals of the correlations, print with the
short=FALSE option

 *-------------*
 *   QUALITY   *
 *-------------*

 Call:corr.test(x = quality[1:8])
Correlation matrix
             low   mid  high critical t_low t_mid t_high t_critical
low         1.00  0.03  0.26    -0.04 -0.02  0.00  -0.11      -0.30
mid         0.03  1.00  0.07     0.00 -0.15  0.17  -0.14      -0.15
high        0.26  0.07  1.00     0.75  0.18  0.01   0.03      -0.17
critical   -0.04  0.00  0.75     1.00  0.26 -0.19  -0.12      -0.09
t_low      -0.02 -0.15  0.18     0.26  1.00 -0.04   0.01      -0.03
t_mid       0.00  0.17  0.01    -0.19 -0.04  1.00   0.24       0.00
t_high     -0.11 -0.14  0.03    -0.12  0.01  0.24   1.00       0.82
t_critical -0.30 -0.15 -0.17    -0.09 -0.03  0.00   0.82       1.00
Sample Size
[1] 27
Probability values (Entries above the diagonal are adjusted for
multiple tests.)
            low  mid high critical t_low t_mid t_high t_critical
low        0.00 1.00 1.00     1.00  1.00  1.00      1          1
mid        0.90 0.00 1.00     1.00  1.00  1.00      1          1
high       0.19 0.73 0.00     0.00  1.00  1.00      1          1
critical   0.85 0.98 0.00     0.00  1.00  1.00      1          1
t_low      0.92 0.45 0.37     0.19  0.00  1.00      1          1
t_mid      0.99 0.38 0.97     0.35  0.86  0.00      1          1
t_high     0.59 0.48 0.87     0.57  0.98  0.23      0          0
t_critical 0.12 0.45 0.40     0.65  0.88  0.99      0          0

To see confidence intervals of the correlations, print with the
```

```
short=FALSE option

*-----------*
*   IMPACT   *
*-----------*

 Call:corr.test(x = impact[1:3])
Correlation matrix
      cost    bi  user
cost  1.00 -0.26 -0.10
bi   -0.26  1.00 -0.33
user -0.10 -0.33  1.00
Sample Size
[1] 22
Probability values (Entries above the diagonal are adjusted for
multiple tests.)
     cost   bi user
cost 0.00 0.49 0.64
bi   0.25 0.00 0.39
user 0.64 0.13 0.00

 To see confidence intervals of the correlations, print with the
short=FALSE option
```

A2. Thresholds for application characteristics (Qaulity, Impact KPI)

Application characteristic	Good	Medium	Poor
Number of low incidents	0-40	41-100	>100
Number of medium incidents	0-30	31-80	>80
Number of high incidents	0-10	11-60	>60
Number of critical incidents	0-5	6-30	>30
Avg. processing time for low incidents [h]	0-40	40-70	>70
Avg. processing time for medium incidents [h]	0-30	31-50	>50
Avg. processing time for high incidents [h]	0-20	21-40	>40
Avg. processing time for critical incidents [h]	0-10	11-30	>31

Table A.1.: Thresholds for application characteristics, considered in Quality KPI

Application characteristic	Good	Medium	Poor
Operational costs [EUR/year]	0-3000	3001-9000	>9000
Number of users	0-3	4-15	>15
High business impact	No		Yes
Strategic relevance	n/a	n/a	n/a

Table A.2.: Thresholds for application characteristics, considered in Impact KPI

A3. Questionnaire: Evaluation of first case study

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Prototype and KPI Evaluation

General questions:

1. What is your job function?

____

2. How many years professional experience do you have?

____

3. What is the maturity level of the EAM initiative at your organization?
Please answer on a scale 0 to 5 - with 0 means that the level of maturity in your opinion is very low, and 5 stands for a very high level of EAM maturity. With values in-between you can adjust your statement.

Very low					**Very high**
☐	☐	☐	☐	☐	☐
0	1	2	3	4	5

4. Which EAM framework do you use at your organization?

Archimate	☐
IAF	☐
Quasar Enterprise	☐
TOGAF	☐
Zachman	☐
We do not use any framework	☐
Other	☐
Which one?____________________	

5. How important is the monitoring of the application landscape's complexity?
Exemplary factors: Number of interfaces...

Unimportant					**Very important**
☐	☐	☐	☐	☐	☐
0	1	2	3	4	5

6. How important is the monitoring of the application landscape's quality?
Exemplary factors: Downtime, number of incidents,...

Unimportant					**Very important**
☐	☐	☐	☐	☐	☐
0	1	2	3	4	5

Technische Universität München

7. How important is the monitoring of the impact in case of application landscape failure?
Exemplary factors: Number of affected users, business impact,...

Unimportant					**Very important**
☐	☐	☐	☐	☐	☐
0	1	2	3	4	5

Questions regarding the prototype:

8. The tool control is very intuitive.

I disagree					**I agree**
☐	☐	☐	☐	☐	☐
0	1	2	3	4	5

9. The user interface design of the tool is clearly structured.

I disagree					**I agree**
☐	☐	☐	☐	☐	☐
0	1	2	3	4	5

10. The tool control is easy to learn.

I disagree					**I agree**
☐	☐	☐	☐	☐	☐
0	1	2	3	4	5

11. The tool provides transparency about issues in the applicaiton landscape and illustrates areas for action.

I disagree					**I agree**
☐	☐	☐	☐	☐	☐
0	1	2	3	4	5

Questions regarding the KPIs:

12. The presented complexity KPI meets my expectations.

I disagree					**I agree**
☐	☐	☐	☐	☐	☐
0	1	2	3	4	5

13. The presented quality KPI meets my expectations.

I disagree					**I agree**
☐	☐	☐	☐	☐	☐
0	1	2	3	4	5

14. The presented impact KPI meets my expectations.

I disagree					**I agree**
☐	☐	☐	☐	☐	☐
0	1	2	3	4	5

Technische Universität München

15. Any further comments? (Pending points, extensions, changes, adjustments)

Thank you for your participation!

A4. Questionnaire: Evaluation of 14 visualizations (concept)

Interview: Using Business Capability based Heat Maps to identify potential Issues in large Enterprise Application Architectures.

Interview partner: ______________________________ Date: _________________

Company: ________________________

General questions regarding your company and position.

1. What industry is your company primarily associated with?
2. How much turnover did your company make last year?
3. How much employees are working at your company?
4. Since when is your company doing EAM?
5. What is your position within the company?
6. Since when are you doing EAM?

Questions regarding the general use of Business Capability Maps (BCM)

7. Does your company make use of the concept of Business Capabilities, respectively a Business Capability Map?

   ☐ Yes ☐ No

8. (**If not**): Why do you not make use of Business Capabilities / BCM?

   ☐ High creation effort ☐ Missing mgmt. support
   ☐ Positioning of applications ☐ High maintenance effort
   ☐ Missing information ☐ Missing contact persons
   ☐ Missing understanding ☐ Missing acceptance
   Others:____

9. What are you using the BCM for?
   (To get an overview? For steering/govern the application landscape?)

1 of 17

10. Since when are you using the BCM and how did it evolve?
(When started the definition? When first draft? Which changes had to be made?)

11. What is the general structure of your BCM?
(Functional clusters? Levels? How advanced respectively complete?)

12. Who or which organization/division defines and maintains the BCM?
(Central/Decentral/Mixed? Who promotes it? Who keeps it „clean"? Responsibilities?)

13. Are there any predefined processes for maintaining/editing/extending the BCM?
(How do they look like?)

14. What are the main challenges for you regarding the creation/maintenance/fielding?

- ☐ High creation effort
- ☐ Missing mgmt. support
- ☐ Positioning of applications
- ☐ High maintenance effort
- ☐ Missing information
- ☐ Missing contact persons
- ☐ Missing understanding
- ☐ Missing acceptance

Others:____

15. Which information are you mapping onto your BCM?

- ☐ User Stories
- ☐ Services
- ☐ Applications
- ☐ Processes
- ☐ Technologies
- ☐ Projects
- ☐ Demands
- ☐ Costs
- ☐ Business objects
- ☐ Responsibilities

Others:____

16. Is it used in practice within projects by the departments (business side)?

- ☐ Not at all
- ☐ Resource Planning
- ☐ Software Development
- ☐ Strategic Planning
- ☐ Risk Management
- ☐ Innovation Management
- ☐ Budget Planning

Others:____

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17. On a scale from 1 to 4, how big do you estimate the benefit of the BCM for the past and the future?

Past	**Future**
☐ 1 very low	☐ 1 very low
☐ 2 somewhat	☐ 2 somewhat
☐ 3 big	☐ 3 big
☐ 4 very big	☐ 4 very big

18. In your opinion, what benefits did the BCM have <u>in the past</u>?
(Regarding methodology, simpler processes, less complexity? Measurable value?)

19. In your opinion, what benefits will the BCM have <u>in the future</u>?
(Regarding methodology, simpler processes, less complexity? Measurable value?)

20. How is the BCM communicated in your company?

☐ Publication in the Intranet/Wiki ☐ Trainings/Workshops
☐ Print (Flyer, Poster, etc.) ☐ Lectures/(Internal) Fair

Others:____

21. In your opinion, is the BCM sufficiently communicated in the relevant departments, IT and business?

IT	**Business**
☐ Yes	☐ Yes
☐ No	☐ No

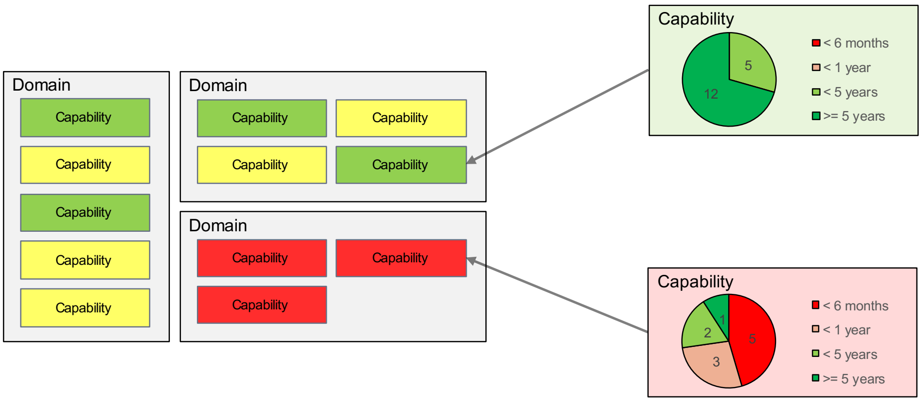
22. Do you use the BCM for the strategic or operational management of the IT landscape?

Strategic (e.g.: Development of long-term target pictures)
☐ Yes, intensive ☐ Yes, frequently ☐ Yes, barely ☐ No

Operational (e.g.: Responsibilities, Positioning in the as-is landscape)
☐ Yes, intensive ☐ Yes, frequently ☐ Yes, barely ☐ No

Comment:

Use Case (01/14): Application Lifecycle



1. Do you use the indicator shown in the Use Case in this or a similar form already in connection with your Business Capability Map?

   ☐ Yes ☐ Planned ☐ No

   Comment:

2. Let us assume that you will implement the given use case in this, or in a modified form in the future in your company, or that you have implemented it already. On a scale from 1 to 4, how big do you estimate its benefit?

   ☐ 1 very low ☐ 2 somewhat ☐ 3 big ☐ 4 very big

   Comment:

3. For what purpose would you use the obtained information?

   ☐ To achieve transparency / for tracking
   ☐ For the evaluation and derivation of action alternatives

4. If the case has not yet been implemented in this or a similar form in your company, on a scale from 1 to 4, how do you assess the feasibility of the case in your company?

   ☐ 1 not at all ☐ 2 poorly ☐ 3 good ☐ 4 very good

   Comment (Missing data? Missing support? Huge effort?):

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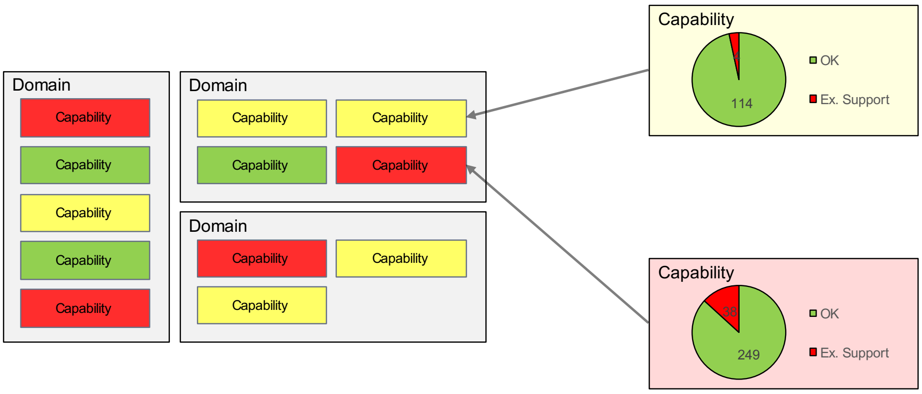
Use Case (02/14): Extended Support



1. Do you use the indicator shown in the Use Case in this or a similar form already in connection with your Business Capability Map?

   ☐ Yes ☐ Planned ☐ No

   Comment:

2. Let us assume that you will implement the given use case in this, or in a modified form in the future in your company, or that you have implemented it already.
   On a scale from 1 to 4, how big do you estimate its benefit?

   ☐ 1 very low ☐ 2 somewhat ☐ 3 big ☐ 4 very big

   Comment:

3. For what purpose would you use the obtained information?

   ☐ To achieve transparency / for tracking
   ☐ For the evaluation and derivation of action alternatives

4. If the case has not yet been implemented in this or a similar form in your company, on a scale from 1 to 4, how do you assess the feasibility of the case in your company?

   ☐ 1 not at all ☐ 2 poorly ☐ 3 good ☐ 4 very good

   Comment (Missing data? Missing support? Huge effort?):

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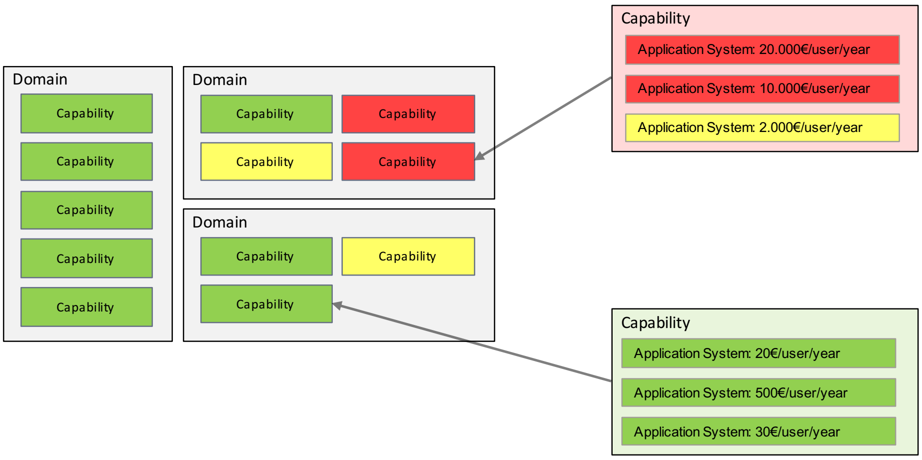
Use Case (03/14): Cost vs. User Count Ratio



1. Do you use the indicator shown in the Use Case in this or a similar form already in connection with your Business Capability Map?

   ☐ Yes ☐ Planned ☐ No

   Comment:

2. Let us assume that you will implement the given use case in this, or in a modified form in the future in your company, or that you have implemented it already. On a scale from 1 to 4, how big do you estimate its benefit?

   ☐ 1 very low ☐ 2 somewhat ☐ 3 big ☐ 4 very big

   Comment:

3. For what purpose would you use the obtained information?

   ☐ To achieve transparency / for tracking
   ☐ For the evaluation and derivation of action alternatives

4. If the case has not yet been implemented in this or a similar form in your company, on a scale from 1 to 4, how do you assess the feasibility of the case in your company?

   ☐ 1 not at all ☐ 2 poorly ☐ 3 good ☐ 4 very good

   Comment (Missing data? Missing support? Huge effort?):

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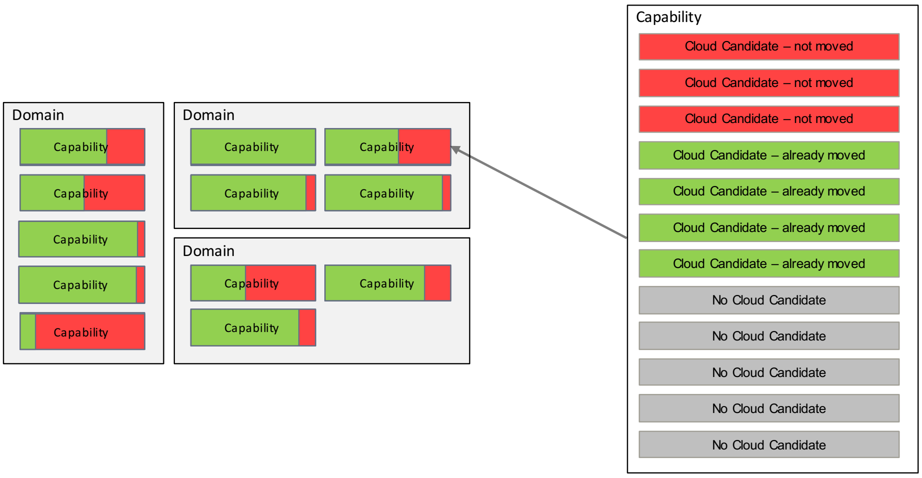
Use Case (04/14): Cloud Candidates / Cloudification



1. Do you use the indicator shown in the Use Case in this or a similar form already in connection with your Business Capability Map?

   ☐ Yes ☐ Planned ☐ No

   Comment:

2. Let us assume that you will implement the given use case in this, or in a modified form in the future in your company, or that you have implemented it already. On a scale from 1 to 4, how big do you estimate its benefit?

   ☐ 1 very low ☐ 2 somewhat ☐ 3 big ☐ 4 very big

   Comment:

3. For what purpose would you use the obtained information?

   ☐ To achieve transparency / for tracking

   ☐ For the evaluation and derivation of action alternatives

4. If the case has not yet been implemented in this or a similar form in your company, on a scale from 1 to 4, how do you assess the feasibility of the case in your company?

   ☐ 1 not at all ☐ 2 poorly ☐ 3 good ☐ 4 very good

   Comment (Missing data? Missing support? Huge effort?):

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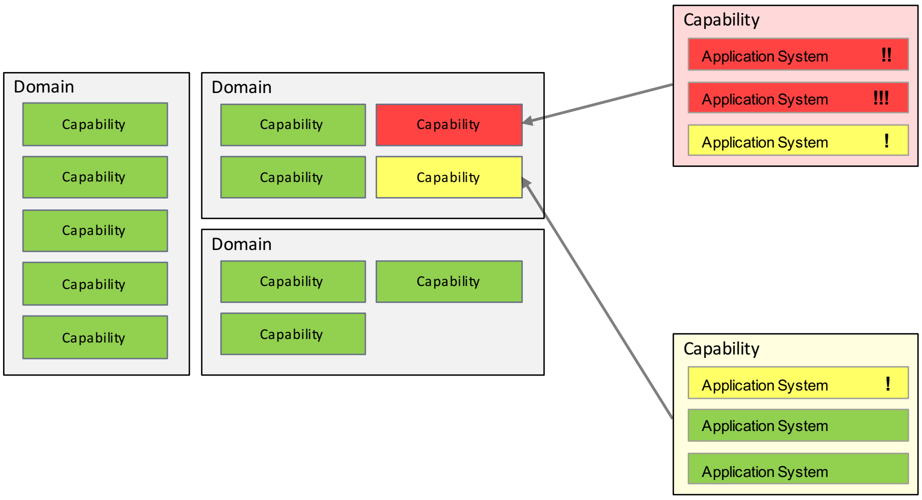
Use Case (05/14): Compliance Issues



1. Do you use the indicator shown in the Use Case in this or a similar form already in connection with your Business Capability Map?

   ☐ Yes ☐ Planned ☐ No

   Comment:

2. Let us assume that you will implement the given use case in this, or in a modified form in the future in your company, or that you have implemented it already.
   On a scale from 1 to 4, how big do you estimate its benefit?

   ☐ 1 very low ☐ 2 somewhat ☐ 3 big ☐ 4 very big

   Comment:

3. For what purpose would you use the obtained information?

   ☐ To achieve transparency / for tracking
   ☐ For the evaluation and derivation of action alternatives

4. If the case has not yet been implemented in this or a similar form in your company, on a scale from 1 to 4, how do you assess the feasibility of the case in your company?

   ☐ 1 not at all ☐ 2 poorly ☐ 3 good ☐ 4 very good

   Comment (Missing data? Missing support? Huge effort?):

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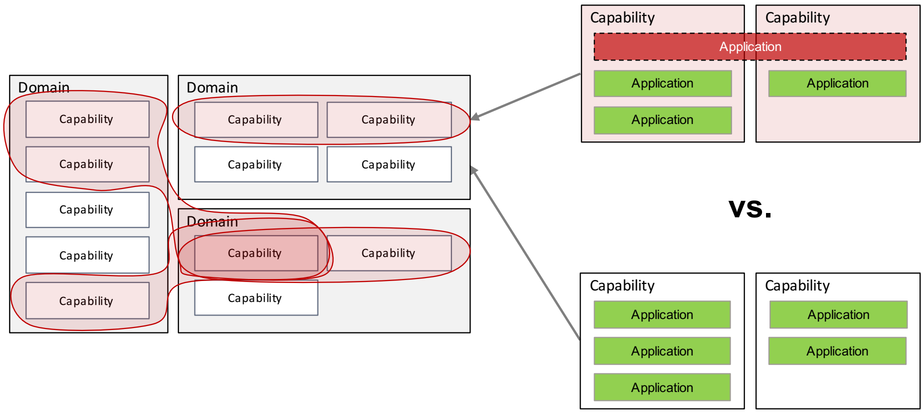
Use Case (06/14): Capability Spanning/Verticalization



1. Do you use the indicator shown in the Use Case in this or a similar form already in connection with your Business Capability Map?

☐ Yes ☐ Planned ☐ No

Comment:

2. Let us assume that you will implement the given use case in this, or in a modified form in the future in your company, or that you have implemented it already. On a scale from 1 to 4, how big do you estimate its benefit?

☐ 1 very low ☐ 2 somewhat ☐ 3 big ☐ 4 very big

Comment:

3. For what purpose would you use the obtained information?

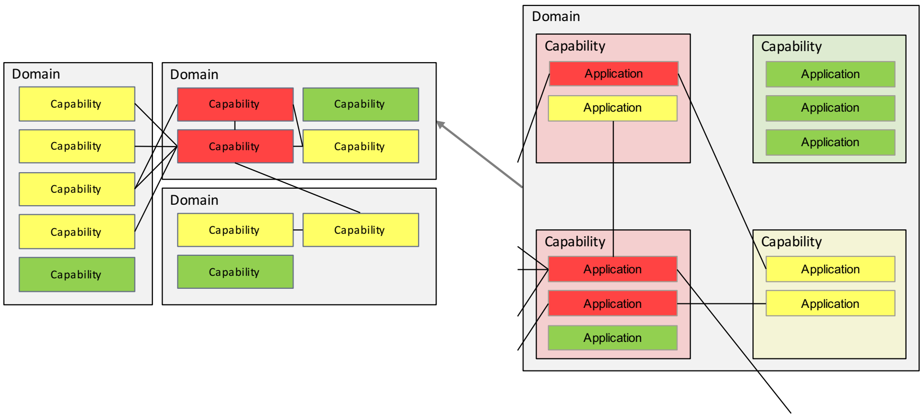
☐ To achieve transparency / for tracking
☐ For the evaluation and derivation of action alternatives

4. If the case has not yet been implemented in this or a similar form in your company, on a scale from 1 to 4, how do you assess the feasibility of the case in your company?

☐ 1 not at all ☐ 2 poorly ☐ 3 good ☐ 4 very good

Comment (Missing data? Missing support? Huge effort?):

Use Case (07/14): Capability Dependencies



1. Do you use the indicator shown in the Use Case in this or a similar form already in connection with your Business Capability Map?

   ☐ Yes ☐ Planned ☐ No

   Comment:

2. Let us assume that you will implement the given use case in this, or in a modified form in the future in your company, or that you have implemented it already.
   On a scale from 1 to 4, how big do you estimate its benefit?

   ☐ 1 very low ☐ 2 somewhat ☐ 3 big ☐ 4 very big

   Comment:

3. For what purpose would you use the obtained information?

   ☐ To achieve transparency / for tracking
   ☐ For the evaluation and derivation of action alternatives

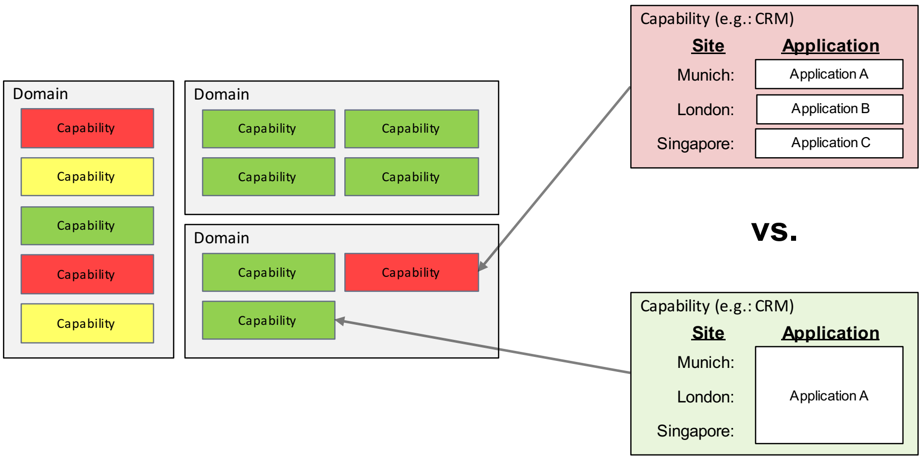
4. If the case has not yet been implemented in this or a similar form in your company, on a scale from 1 to 4, how do you assess the feasibility of the case in your company?

   ☐ 1 not at all ☐ 2 poorly ☐ 3 good ☐ 4 very good

   Comment (Missing data? Missing support? Huge effort?):

10 of 17

Use Case (08/14): Harmonization Potential/Degree



1. Do you use the indicator shown in the Use Case in this or a similar form already in connection with your Business Capability Map?

   ☐ Yes ☐ Planned ☐ No

   Comment:

2. Let us assume that you will implement the given use case in this, or in a modified form in the future in your company, or that you have implemented it already.
   On a scale from 1 to 4, how big do you estimate its benefit?

   ☐ 1 very low ☐ 2 somewhat ☐ 3 big ☐ 4 very big

   Comment:

3. For what purpose would you use the obtained information?

   ☐ To achieve transparency / for tracking
   ☐ For the evaluation and derivation of action alternatives

4. If the case has not yet been implemented in this or a similar form in your company, on a scale from 1 to 4, how do you assess the feasibility of the case in your company?

   ☐ 1 not at all ☐ 2 poorly ☐ 3 good ☐ 4 very good

   Comment (Missing data? Missing support? Huge effort?):

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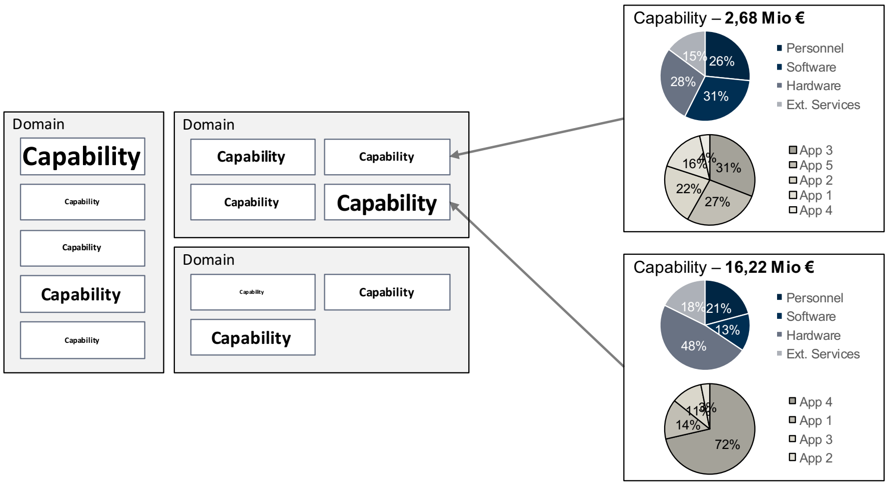
Use Case (09/14): It Costs



1. Do you use the indicator shown in the Use Case in this or a similar form already in connection with your Business Capability Map?

☐ Yes ☐ Planned ☐ No

Comment:

2. Let us assume that you will implement the given use case in this, or in a modified form in the future in your company, or that you have implemented it already.
On a scale from 1 to 4, how big do you estimate its benefit?

☐ 1 very low ☐ 2 somewhat ☐ 3 big ☐ 4 very big

Comment:

3. For what purpose would you use the obtained information?

☐ To achieve transparency / for tracking
☐ For the evaluation and derivation of action alternatives

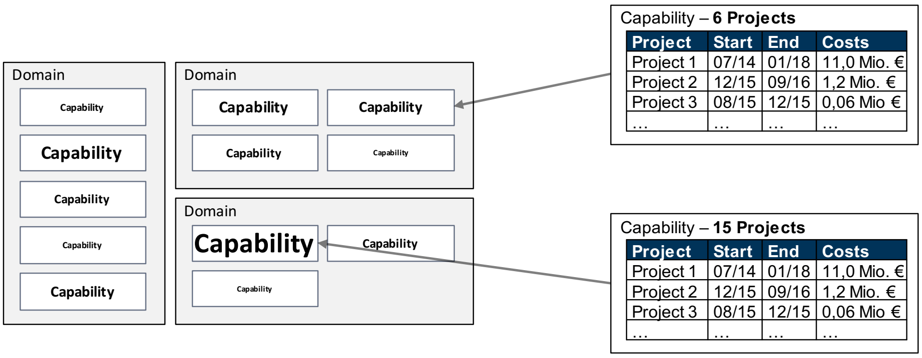
4. If the case has not yet been implemented in this or a similar form in your company, on a scale from 1 to 4, how do you assess the feasibility of the case in your company?

☐ 1 not at all ☐ 2 poorly ☐ 3 good ☐ 4 very good

Comment (Missing data? Missing support? Huge effort?):

12 of 17

Use Case (10/14): Projects



1. Do you use the indicator shown in the Use Case in this or a similar form already in connection with your Business Capability Map?

   ☐ Yes ☐ Planned ☐ No

   Comment:

2. Let us assume that you will implement the given use case in this, or in a modified form in the future in your company, or that you have implemented it already. On a scale from 1 to 4, how big do you estimate its benefit?

   ☐ 1 very low ☐ 2 somewhat ☐ 3 big ☐ 4 very big

   Comment:

3. For what purpose would you use the obtained information?

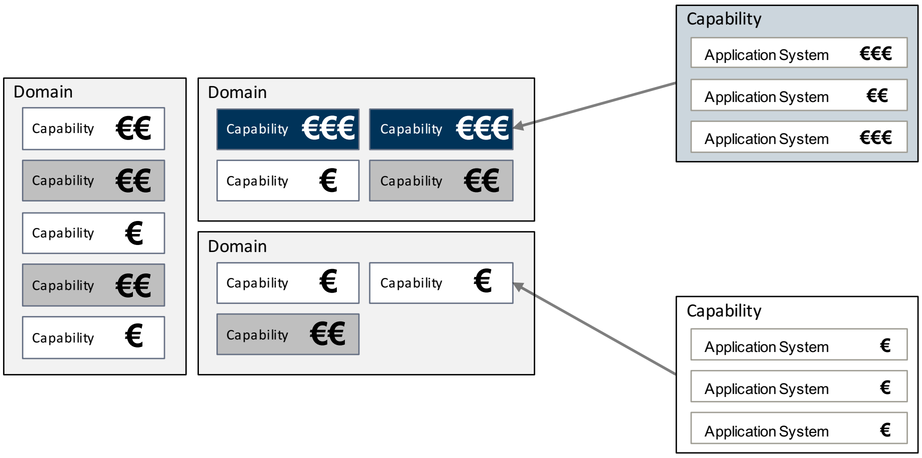
   ☐ To achieve transparency / for tracking
   ☐ For the evaluation and derivation of action alternatives

4. If the case has not yet been implemented in this or a similar form in your company, on a scale from 1 to 4, how do you assess the feasibility of the case in your company?

   ☐ 1 not at all ☐ 2 poorly ☐ 3 good ☐ 4 very good

   Comment (Missing data? Missing support? Huge effort?):

Use Case (11/14): Business Impact



1. Do you use the indicator shown in the Use Case in this or a similar form already in connection with your Business Capability Map?

   ☐ Yes ☐ Planned ☐ No

   Comment:

2. Let us assume that you will implement the given use case in this, or in a modified form in the future in your company, or that you have implemented it already. On a scale from 1 to 4, how big do you estimate its benefit?

   ☐ 1 very low ☐ 2 somewhat ☐ 3 big ☐ 4 very big

   Comment:

3. For what purpose would you use the obtained information?

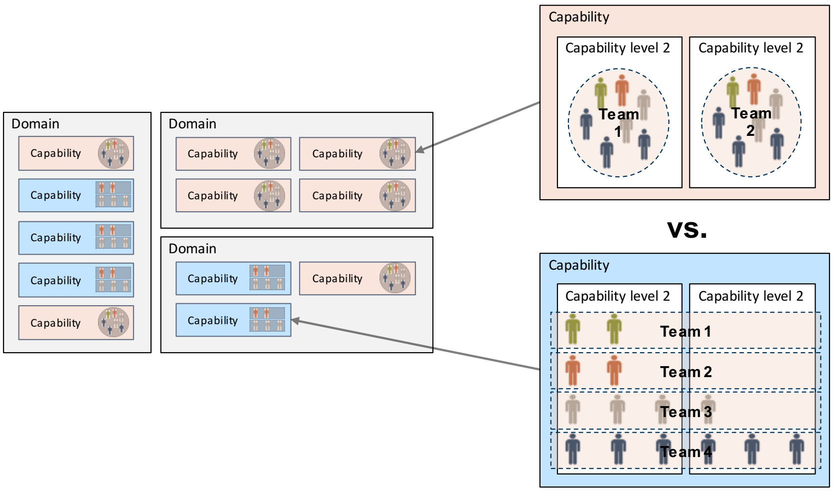
   ☐ To achieve transparency / for tracking
   ☐ For the evaluation and derivation of action alternatives

4. If the case has not yet been implemented in this or a similar form in your company, on a scale from 1 to 4, how do you assess the feasibility of the case in your company?

   ☐ 1 not at all ☐ 2 poorly ☐ 3 good ☐ 4 very good

   Comment (Missing data? Missing support? Huge effort?):

Use Case (12/14): Agile Team Organization



1. Do you use the indicator shown in the Use Case in this or a similar form already in connection with your Business Capability Map?

   ☐ Yes ☐ Planned ☐ No

   Comment:

2. Let us assume that you will implement the given use case in this, or in a modified form in the future in your company, or that you have implemented it already.
   On a scale from 1 to 4, how big do you estimate its benefit?

   ☐ 1 very low ☐ 2 somewhat ☐ 3 big ☐ 4 very big

   Comment:

3. For what purpose would you use the obtained information?

   ☐ To achieve transparency / for tracking
   ☐ For the evaluation and derivation of action alternatives

4. If the case has not yet been implemented in this or a similar form in your company, on a scale from 1 to 4, how do you assess the feasibility of the case in your company?

   ☐ 1 not at all ☐ 2 poorly ☐ 3 good ☐ 4 very good

   Comment (Missing data? Missing support? Huge effort?):

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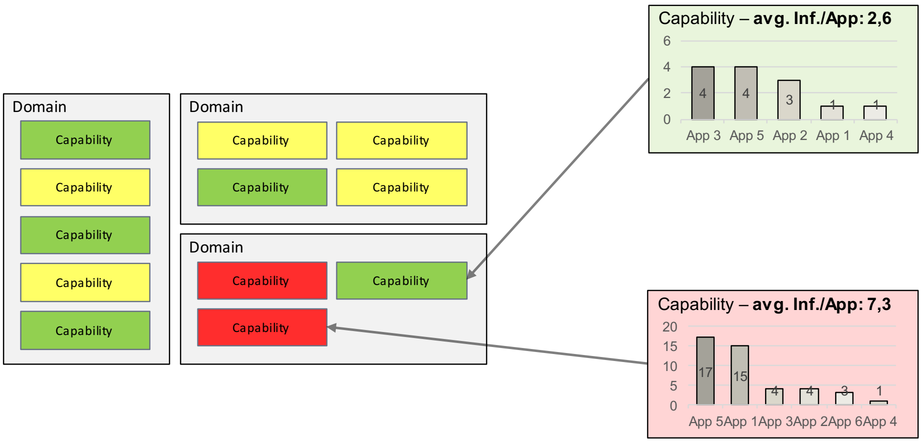
Use Case (13/14): Infrastructure Components



1. Do you use the indicator shown in the Use Case in this or a similar form already in connection with your Business Capability Map?

   ☐ Yes ☐ Planned ☐ No

   Comment:

2. Let us assume that you will implement the given use case in this, or in a modified form in the future in your company, or that you have implemented it already.
   On a scale from 1 to 4, how big do you estimate its benefit?

   ☐ 1 very low ☐ 2 somewhat ☐ 3 big ☐ 4 very big

   Comment:

3. For what purpose would you use the obtained information?

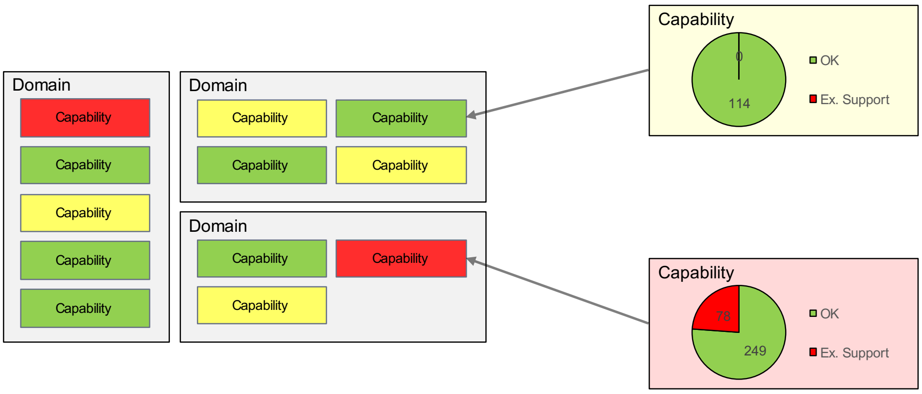
   ☐ To achieve transparency / for tracking
   ☐ For the evaluation and derivation of action alternatives

4. If the case has not yet been implemented in this or a similar form in your company, on a scale from 1 to 4, how do you assess the feasibility of the case in your company?

   ☐ 1 not at all ☐ 2 poorly ☐ 3 good ☐ 4 very good

   Comment (Missing data? Missing support? Huge effort?):

Use Case (14/14): Infrastructure Components – Ext. Support



1. Do you use the indicator shown in the Use Case in this or a similar form already in connection with your Business Capability Map?

   ☐ Yes ☐ Planned ☐ No

   Comment:

2. Let us assume that you will implement the given use case in this, or in a modified form in the future in your company, or that you have implemented it already. On a scale from 1 to 4, how big do you estimate its benefit?

   ☐ 1 very low ☐ 2 somewhat ☐ 3 big ☐ 4 very big

   Comment:

3. For what purpose would you use the obtained information?

   ☐ To achieve transparency / for tracking
   ☐ For the evaluation and derivation of action alternatives

4. If the case has not yet been implemented in this or a similar form in your company, on a scale from 1 to 4, how do you assess the feasibility of the case in your company?

   ☐ 1 not at all ☐ 2 poorly ☐ 3 good ☐ 4 very good

   Comment (Missing data? Missing support? Huge effort?):

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