Managing Multi-Cloud Systems

A framework for effective management and governance of multivendor cloud arrangements



MSc Thesis by Amon Schrama

TU Delft

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A framework for effective management and governance of multivendor cloud arrangements

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Preface

Dear reader,

The thesis before you is the result of half a year of work on multi-cloud systems. I started the master's programme Management of Technology because I wanted to learn how to bridge the gap between technology and organization. This thesis reflects that, as multi-cloud is approached from an organizational perspective. I chose this specific topic after specializing in ICT Design & Management. Cloud computing interested me, and after diving deeper into the subject, I came across multi-cloud. To me, this was the perfect opportunity to combine my interests with my knowledge.

I have written this thesis during the COVID-19 pandemic. This was a bit strange, as almost everything had to be done from home. I was lucky enough to have the opportunity to go to the office now and then, but the pandemic still influenced this work. Most meetings and interviews were online, and it was hard to connect with colleagues and fellow students.

Above all, I am proud to present this work to you, and thankful to the people that have helped me accomplish this. First of all, I would like to thank Marijn for all the feedback he provided during this process. The regular meetings helped me stay on track and provided useful insights to bring my thesis to a higher level. I would also like to thank Haiko for putting things into perspective. We did not have many meetings, but due to his comments, I often came away with a different point of view. A final word of thanks is for Thomas, who supported me throughout the process and helped me find my way at PwC.

Amon Schrama

The Hague, June 2021

Summary

This thesis focuses on the management of multi-cloud systems. Multi-cloud is a form of cloud computing in which services are combined with each other. Cloud computing means the scalable provision of IT services through network access. With multi-cloud, these services are combined. An initial exploration of the subject shows that there is a variety of technical solutions to approach multi-cloud. However, there is lack of knowledge on the organizational aspects of governance and management. The aim of this research is to fill this gap.

The research objective is to find a way to effectively govern multi-cloud systems. To do this, a framework is designed, which is based on the answers to the research questions. The main research question entails how to effectively manage multi-cloud systems. This question is decomposed into four sub questions, which aim to find a proper definition of multi-cloud systems, and challenges, factors, and requirements associated with its management. The answers to all these questions should provide the foundation on which the ultimate framework is constructed.

The research approach consists of a literature review and a multiple-case study. The literature review is performed according to the PRISMA statement, and aims to define multi-cloud systems and identify challenges, factors, requirements, and mechanisms in the multi-cloud environment. The findings should provide preliminary answers to the research questions. The multiple-case study should then confirm or refute these answers. For the multiple-case study, interviews are conducted at organizations that use multi-cloud systems. When the answers are clear and translated to a framework, this will be evaluated by interviewing a subject matter expert.

The literature review provides a definition of multi-cloud systems. In multi-cloud systems, multiple independent public clouds are combined. This can either be a library-based or a service-based approach. In the former, applications from different cloud providers are connected. The latter describes a multi-cloud system where multiple cloud services are combined to create a single application.

Findings of the literature review show that multisourcing theories are relevant for this research. From these theories, multiple governance types are derived which are relevant in this context. These include inter-organizational, relational, and contractual governance. Besides, multisourcing theory shows that there are different types of arrangements. Furthermore, studies on cloud management identify business governance as a relevant factor, on both the service and the technical level. Furthermore,

Coordination Theory is found to be applicable in this case, as it focuses on managing interdependencies between stakeholders.

From the literature review, a vast number of potential factors is derived. A full list of these is shown in Appendix C. These factors include interoperability, organizational maturity, and the types of governance from the previous paragraph. Besides these factors, a number of challenges is derived. These have some overlap with the factors, and include interoperability, security, and privacy. Furthermore, the review identifies requirements and corresponding mechanisms, like a cloud office, decision-making structures, and service level agreements. These findings are then combined into a conceptual framework, which is presented in Figure 2.3.

After concluding the literature review, the research moves on to the multiple-case study. Interviews are performed at three different organizations. The goal of these interviews is to confirm or refute the challenges, factors, and requirements found in the literature review. An interesting pattern that the cases show is the use of an integration platform. Such a platform stimulates interconnectivity and -operability, and reduces complexity in the system. Furthermore, it emphasizes the need for collaboration in the multi-cloud context.

Another essential factor in the multi-cloud environment is secure data management. This is also supported by an integration platform. The interviews also show another form of contracts: Experience Level Agreements. These are experience-driven instead of service-driven, and focus more on the end user. Factors that are identified or confirmed by the interviews are risk, trust, relationship, and data management, security and privacy, interoperability, and organizational maturity. A challenge that occurs besides the ones identified in the literature review is interconnectivity, which is closely related to interoperability. Requirements that are deducted from these findings are a clear division of roles, clear, feasible contracts and agreements, clear communication, formulated objectives, and proper data management.

All these findings form the foundation for the framework presented in Figure 4.1. The rough structure is based on the governance types found in the literature review. Requirements and factors are then inserted at the suitable place in the framework. In short, the framework describes what to determine for each type of governance. This starts at an intra-organizational level, specifically on the service level. Here, business objectives are formulated, and competencies of the organization are assessed. Besides, roles and responsibilities are allocated and a cloud office is set up. Then comes the technical level, in which IT maturity is determined and the architecture is defined. Here, the integration platform comes into play. Furthermore, based on the IT maturity, a mediator can be appointed to assist with the inter-organizational governance.

The inter-organizational governance starts on a contractual level. This means that objectives from before should be translated into requirements on service, security, and optionally experience. Besides, roles and responsibilities of the vendors should be assigned. After this, relationship management is important to build trustful and

mature relationships. This way, the framework provides a guideline for constructing a governance and management structure within the organization.

External validity of the findings is sufficient. The external validity is approached by replication and explicitly asking a subject matter expert during the evaluation interview. Most findings are generalizable, which substantiates the credibility of the framework. Furthermore, th evaluation shows that the framework is useful because it triggers organizations to think about how they manage their cloud systems. In the future, the framework can be applied in a practical setting. This would further assess the usability and relevance of the framework.

Contents

Preface i

Summary ii

List of Figures viii

List of Tables ix

List of Acronyms x

1 Introduction 1
- 1.1 Background of cloud computing . . . 1
  - 1.1.1 The rise of cloud computing . . . 1
  - 1.1.2 Transition to multi-cloud systems . . . 3
- 1.2 Problem description . . . 4
  - 1.2.1 Problem analysis . . . 4
  - 1.2.2 Problem definition . . . 5
- 1.3 Research objectives . . . 6
- 1.4 Research questions . . . 6
- 1.5 Methodology . . . 7
  - 1.5.1 Research approach . . . 7
  - 1.5.2 Methodology and instruments . . . 9

2 Multi-cloud management in theory 11
- 2.1 Search description and selection criteria . . . 12
- 2.2 Single-cloud management and governance . . . 13
  - 2.2.1 IT management . . . 13
  - 2.2.2 Governing the cloud . . . 14
- 2.3 Multi-cloud techniques and technologies . . . 17
  - 2.3.1 Defining multi-cloud systems . . . 17
  - 2.3.2 Standardization in cloud environments . . . 18
  - 2.3.3 Multi-cloud frameworks and techniques . . . 19
  - 2.3.4 Multi-cloud management . . . 20
- 2.4 Multisourcing arrangements of IT services . . . 21
  - 2.4.1 The evolution of IT outsourcing . . . 21

2.4.2 Governance types and mechanisms in multisourcing 22
2.4.3 Coordination Theory in multisourcing 24
2.5 Conclusions 25
2.5.1 Findings 25
2.5.2 Conceptual framework 27
2.5.3 Theory versus practice; the conceptual framework applied . . . 29

3 A practical perspective **31**
3.1 Goals of the multiple-case study 32
3.1.1 Challenges 32
3.1.2 Factors 32
3.1.3 Requirements 33
3.1.4 Overview 33
3.2 Cases 34
3.2.1 Case 1 34
3.2.2 Case 2 37
3.2.3 Case 3 40
3.2.4 Case 4 42
3.3 Cross-case analysis 44
3.3.1 Approach 44
3.3.2 Qualitative data analysis 45
3.3.3 Integration platform (as-a-service) 46
3.3.4 Secure data management 48
3.3.5 Collaboration and dividing roles 49
3.3.6 From SLAs to XLAs 50
3.4 Validation of the multiple-case study 50
3.4.1 Internal validation 50
3.4.2 External validation 51
3.5 Conclusions from the interviews 51
3.5.1 Findings 51
3.5.2 Towards a governance and management framework 53

4 Coordination framework **54**
4.1 Elements of the framework 56
4.1.1 Service level 56
4.1.2 Technical level 57
4.1.3 Contract level 58
4.1.4 Relational level 59
4.1.5 Overview 59
4.2 Application of the framework 60
4.2.1 A guideline for IT managers 60
4.2.2 Use case: Effective multi-cloud management 61
4.3 Composing the framework 65
4.3.1 Goals 65
4.3.2 Challenges 65

4.3.3 Factors and requirements . . . 66
4.3.4 Techniques and mechanisms . . . 66
4.4 Considerations . . . 67
4.4.1 A nuanced view on multi-cloud . . . 67
4.4.2 Cost-effectiveness in multi-cloud arrangements . . . 68
4.4.3 Integration of services . . . 68
4.4.4 Partnership-oriented model . . . 70

5 Evaluation **72**
5.1 Evaluation approach . . . 72
5.2 Evaluation results . . . 73
5.2.1 Evaluation of the findings . . . 73
5.2.2 Evaluation of the framework . . . 74
5.2.3 Discussion . . . 75

6 Conclusions **76**
6.1 Research questions . . . 76
6.2 Framework . . . 78
6.3 Future research . . . 78

7 Discussion and reflection **79**
7.1 Research limitations . . . 79
7.2 Discussion on the findings of this thesis . . . 80
7.3 Relevance of this work . . . 81
7.3.1 Managerial relevance . . . 81
7.3.2 Academic relevance . . . 81
7.4 Personal reflection . . . 81

References **83**

A System analysis **88**
A.1 The multi-cloud ecosystem . . . 88
A.1.1 Stakeholders and their position . . . 88
A.1.2 Multi-cloud ecosystem model . . . 91

B Search description of the literature review **93**

C Factors and mechanisms **94**

D Interviews **97**
D.1 Interview questions cases . . . 97
D.2 Interview questions evaluation . . . 98

List of Figures

1.1 Cloud service models, along with the resources that are managed by the cloud vendor in each service model 2
1.2 Flow of services in the multi-cloud ecosystem 5
1.3 Steps of the research approach, along with data collection methods and underlying theory 7

2.1 Service-based (left) and library-based (right) multi-cloud 19
2.2 Three IT multisourcing models. From left to right: mediated, direct, and direct-overlapping (Wiener & Saunders, 2014) 24
2.3 Conceptual model of theory on multi-cloud management 28

3.1 Dataflow in a library-based multi-cloud system with an integration platform 47

4.1 Framework for effective governance and management of multi-cloud systems 55
4.2 Agreements and interactions in a service-based multi-cloud environment 70

A.1 Power/Interest grid for the multi-cloud ecosystem 90
A.2 Flow of services in the multi-cloud ecosystem 91

List of Tables

1.1 Approximation of work done for this thesis 9

2.1 Overview of factors in multi-cloud management and corresponding mechanisms 26

3.1 Results of Case 1 37
3.2 Results of Case 2 39
3.3 Results of Case 3 42
3.4 Results of Case 4 44
3.5 Data display of all factors in the multiple-case study 46
3.6 Number of information sources for each case study 50

B.1 Literature search description and results 93

C.1 Overview of all factors and corresponding mechanisms identified in the literature review 95
C.2 Simplified overview of factors and corresponding mechanisms 96

D.1 Interview questions for the multiple-case study 98
D.2 Interview questions for the evaluation 99

List of Acronyms

API Application Programming Interface

BLO Business Level Objective

CAMP Cloud Application Management for Platforms

EAI Enterprise Application Integration

ESB Enterprise Service Bus

IaaS Infrastructure-as-a-Service

iPaaS Integration Platform-as-a-Service

OLA Operational Level Agreement

PaaS Platform-as-a-Service

QoE Quality of Experience

QoS Quality of Service

SaaS Software-as-a-Service

SLA Service-Level Agreement

SOA Service-Oriented Architecture

TOSCA Topology and Orchestration Specification for Cloud Applications

XLA Experience-Level Agreement

Chapter 1

Introduction

This thesis focuses on the management and governance of multi-cloud systems. This is a form of cloud computing in which the services of multiple providers are combined. In order to understand these systems, there has to be proficient knowledge on cloud computing in general. From there, one can zoom in on this particular form and identify the associated challenges. This introduction provides some background on the subject. This is divided in two parts; one on cloud computing and one on multi-cloud systems. This is followed by the problem description for this thesis, along with research objectives and questions. The chapter is concluded with the approach and methodology used for this research.

1.1 Background of cloud computing

This section provides an overview of what cloud computing is, and a background of the problem addressed by this thesis. The first part focuses on cloud computing in general, while the second part zooms in on multi-cloud systems.

1.1.1 The rise of cloud computing

Over the last decade, cloud computing has seen a massive growth in usage. The on-demand access to a variety of IT resources is popular among many organizations. A general definition of cloud computing is that it provides network access to a range of scalable IT resources, like servers, processing power, and other services (Mell et al., 2011). Major advantages of this model are that the services have high scalability, are accessible from anywhere, and are hosted and maintained by a provider. For businesses, this should result in cost savings, reliability, mobility, and many other benefits. For these reasons, many organizations are moving to the cloud.

Cloud computing comes in three service models: Infrastructure-, Platform-, and Software-as-a-Service (IaaS, PaaS, and SaaS, respectively). Usually, SaaS services come in the form of an application, IaaS services provide the underlying infrastruc-

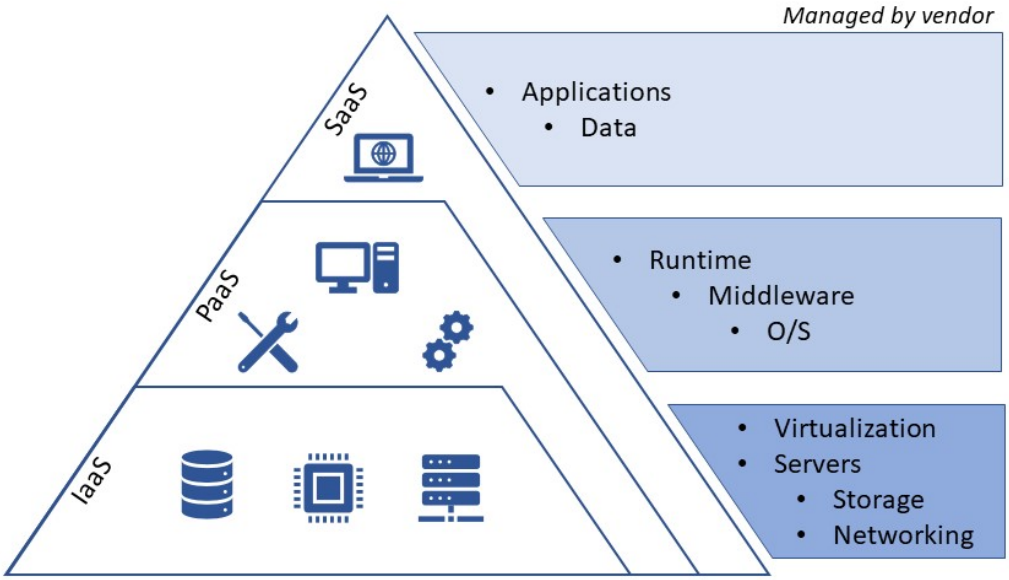

Figure 1.1: Cloud service models, along with the resources that are managed by the cloud vendor in each service model

ture, and PaaS services function as middleware, or a platform where applications can be build (Mell et al., 2011). A visual representation of these service models can be found in Figure 1.1. Note that in the cases of SaaS or PaaS, the underlying resources are also managed by the cloud provider. Beside these service models, there are four different deployment models. These are public, private, community, and hybrid cloud (Mell et al., 2011). Public clouds are available to multiple organizations, and are most commonly used. Private clouds are available to only one organization, and may be hosted on the premises of that organization. A community cloud is available to a select group of organizations. Finally, a hybrid cloud is a combination of at least two of the aforementioned deployment models.

Nowadays, there is a wide array of cloud service providers, with tech giants like Microsoft, Amazon, and Google at the front line. Some of these vendors provide a great variety of cloud services, while others are specialized in a specific solution. There are plenty of possibilities, and it can be difficult to find the right fit between organization and provider. Besides, these cloud providers have different capabilities and prices. One provider may excel at storage capabilities, while another provides exceptional data analytics. In such cases, it can be hard to select the right provider. This choice can be even more difficult when an organization wants to combine these services. Such a combination can be defined as a multi-cloud application or system, which is the next step in cloud computing.

1.1.2 Transition to multi-cloud systems

While cloud computing from a single provider presents a remarkable opportunity for organizations to arrange their IT landscape, it is not yet optimal. As described in the previous paragraph, each cloud provider offers different possibilities and capabilities. For many organizations, there is often no single system that covers all their wishes. This results in less functionality than the organization desires. To overcome this barrier, multi-cloud systems are introduced.

In a multi-cloud environment, cloud services or applications from different providers are used simultaneously. As described in the previous section, this may be beneficial for organizations as they can 'shop around' for the best parts of the system they want to use. This leads to a so-called 'best-of-breed' solution, which is a solution that consists of the most optimal components for the organization's purpose. However, it is often not that easy. Although cloud computing is being widely adopted, some issues still remain. One of those issues is a lack of standardization on multiple levels (Akande et al., 2013). For instance, this can be a lack of standardization of cloud computing application user interfaces (APIs), but also of service level agreements (SLAs). This decreases the interoperability of services by different cloud providers, and is therefore hindering the optimization of cloud efficiency. The problem where services from different cloud providers are difficult to combine is called a vendor lock-in. This problem can also make it difficult to migrate an application from one provider to another.

Multi-cloud systems hold a lot of promise, and pose potential benefits like cost-effectiveness and increased flexibility. Besides, they provide the possibility to achieve a higher functionality than cloud computing services from a single provider. However, such systems are not yet as popular as regular (single) cloud computing. While the benefits are clear, multi-cloud may bring risk and uncertainty due to the novelty of the technology. Multi-cloud brings both technical and organizational complexity. Technical solutions to overcome certain barriers exist, but the organizational complexity remains. The system analysis in Appendix A displays this complexity, and shows the vast amount of stakeholders in this environment. The Power/Interest grid in Figure A.1 shows that the core players in the multi-cloud environment are the customer, the different cloud service providers, and in a slightly smaller role, the multi-cloud platform provider. The customer is the organization that procures the cloud services, the cloud service providers are the companies that supply them, and the multi-cloud platform provider supplies a solution to overcome technical barriers in the multi-cloud environment.

The main goal of the customer in a multi-cloud environment is to procure a solution that has the desired functionality for the organization. This solution consists of services supplied by the cloud service providers. These providers would like to sell as many of their products as possible to the customer. From their point of view, it would be beneficial if the entire solution consisted of their services, as this would make the customer more dependent on them. This creates a vendor lock-in. This perspective also shows why cloud service providers do not have a natural incentive to standardize their services. Finally, the multi-cloud platform provider tries to cover

the gap between the customer and the cloud service providers by supplying some form of middleware. Still, this mostly covers the technical aspects of the system. The customer still has to manage the organizational side of this complex system, which can be difficult due to the conflicting interests of the customer and the cloud service providers. This leads to the problems addressed by this thesis. The next section further analyzes this, and provides a definition of the problem.

1.2 Problem description

The background of the problem sketches out what multi-cloud entails, what its benefits are, and which difficulties are present. This section further describes the problem, which ultimately leads to the problem definition. For this purpose, a system analysis was conducted, which can be found in Appendix A. This analysis is briefly discussed in the first part of this section. A visualization of the multi-cloud ecosystem that results from this analysis is shown in Figure 1.2, which is explained in detail in Appendix A. This analysis is used to clearly define the problem that this thesis addresses, which is stated in the second part of this section. From there, the research objectives can be formulated.

1.2.1 Problem analysis

The adoption and use of cloud computing are still on the rise, but some challenges remain. Due to interoperability problems and a lack of standardization among cloud providers, it can be difficult to combine services from different cloud providers and create a multi-cloud environment. It is impossible to present a single solution to these problems, as there are many different stakeholders involved who do not have an incentive to standardize their offerings. Besides, it is difficult to determine which of the stakeholders should do this. Figure 1.2 displays this. The cloud service providers could standardize their offerings, but they could also say that either the software vendors or the physical infrastructure providers should do this. Because of these intricacies, a single solution is non-viable, and solutions should be tailor-made. Therefore, this thesis does not aim to solve all issues around multi-cloud, but mitigate them instead.

In order to mitigate these challenges, there exists a variety of multi-cloud solutions and interfaces. However, the current state of research on such solutions is still very technical. From an organizational perspective, it is unclear how to use and manage multi-cloud systems and applications. Solutions are there, but the knowledge on how to apply them in the organizational context is not. The core players in this context have been named in the previous paragraph. Each has their own perspective on this problem. The cloud service and the multi-cloud platform providers offer technical products. The customer has the largest interest in the organizational side of this problem. The question is how the other core players fit into this organizational picture. How all actors and services connect to each other is shown in Figure 1.2. It

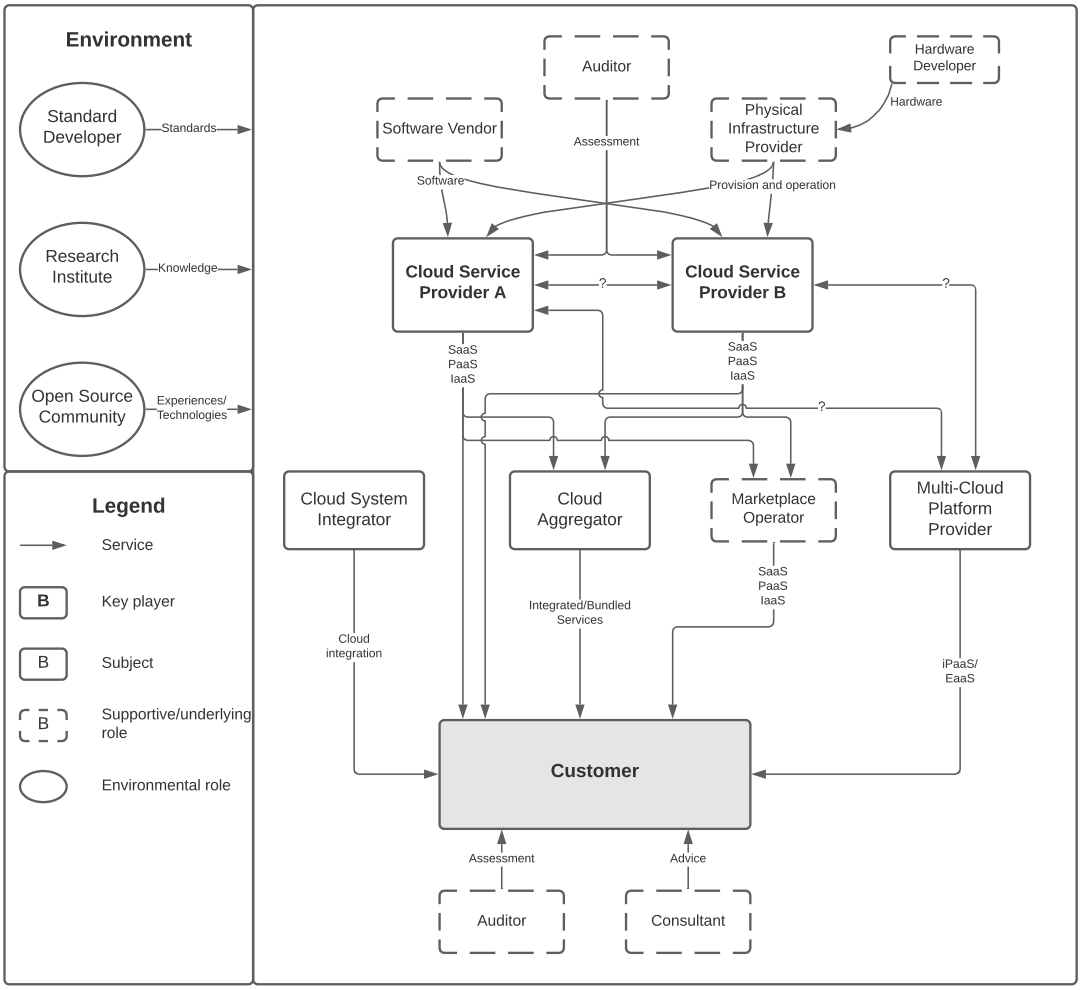

Figure 1.2: Flow of services in the multi-cloud ecosystem

becomes clear that there are many intricacies involved in this environment, and some connections not yet clear. This portrays why multi-cloud management is that difficult.

1.2.2 Problem definition

There is a variety of technical solutions for multi-cloud management. However, due to the novelty of these solutions, it is unclear how to orchestrate them. The problem of orchestration can be decomposed in the difficulties described in the previous section. These difficulties are further portrayed by Figure 1.2, which is elaborated on in Appendix A.

In conclusion, there is a lack of knowledge on how to manage multi-cloud systems and applications from an organizational perspective. This thesis aims to fill this gap, and identify ways to handle multiple clouds within an organization. This leads to the objectives in the following section.

1.3 Research objectives

It is clear that there is a scarcity of research on how to manage multi-cloud systems. So, the general objective of this thesis is to fill this gap. Still, this objective can be interpreted in multiple ways and should be precisely defined. It should be noted that the research specifically focuses on management of multi-cloud systems, and not on any other parts of the life cycle. Besides, the question is on 'how' to manage such systems, and can therefore be qualified as qualitative research. The goal is to explore organizational factors and mechanisms that play a role in the management of multi-cloud systems, and assess their possible influence.

The final deliverable of this research is a framework in which these factors and mechanisms are classified. It should provide guidance and clarity in the complexities of managing multi-cloud systems. After developing the framework, it is also evaluated. Besides, the framework may be extended in the future.

1.4 Research questions

In order to realize the objective, a main research question is proposed. This is further substantiated with a number of sub-questions, which also make it possible to manage the research in an effective way. The main research question is:

How can multi-cloud systems be effectively managed within an organization?

This question grasps all concepts proposed in the previous sections, and formulates the objective of this thesis. Still, these concepts must be well defined. Effective management means that the desired functionality of a multi-cloud system is reached. This includes user friendliness and quality of the provided services. This is related to the degree of asset utilization, which can be a metric for IT governance performance (Weill & Ross, 2005). The sub-questions should provide a way to give a legitimate answer to the main research question. The following sub-questions are formulated:

1. *What are multi-cloud systems?*
2. *Which challenges are encountered when managing multi-cloud systems?*
3. *Which factors influence the quality of multi-cloud management?*
4. *What are requirements for effective management of multi-cloud?*

The aim of the first sub-question is to properly define the terminology of multi-cloud systems, while the others focus on the points that come with the management of them. Factors, problems, and requirements all play a role in the effective management of a multi-cloud system, and should therefore be identified. After identifying challenges, the factors that play a role in the multi-cloud environment can be identified. From there, the requirements for effective multi-cloud management can be deducted. When these points are all clear, it is possible to present an overview of how to effectively manage such systems. This can then be translated into the final framework.



Figure 1.3: Steps of the research approach, along with data collection methods and underlying theory

1.5 Methodology

This section describes the research approach and methods to achieve the research objectives and answer the research questions. The first part of this section describes the approach in general, which steps it contains, and how they aim to answer the research questions. The second part addresses the theories that are used for this approach.

1.5.1 Research approach

This research focuses on the 'how' question, which should ultimately result in a framework for effective multi-cloud management. This goal requires qualitative research. The main approach to achieve the research objectives is by systematic literature review and a multiple-case study, consisting of small cases. In the case studies, semi-structured interviews are used as a research instrument. The final deliverable is a framework for effective multi-cloud management. This framework follows from both the literature review and the case studies. The framework is also evaluated. These steps are displayed in Figure 1.3, along with the data collection methods and the underlying theory. This theory is briefly discussed in the next section. Besides, the approach to each of these steps is elaborated on in the corresponding chapters. The framework is based on the findings from the literature review and the multiple-case study. Building the framework takes place between steps two and three in Figure 1.3. The evaluation considers both the results from the first two research steps and the framework.

The first step to answering the sub-questions is to find possible variables and relations between them. These findings can then be used to hypothesize how the system works and substantiate the direction of the framework. To do this, an elaborate literature review is performed. This review is meant to find relevant factors, requirements, and mechanisms. These can be identified by exploring relevant literature on multi-cloud, but also on similar arrangements. The findings should result in preliminary answers and hypotheses to some of the sub-questions. The literature review is performed in accordance with the guidelines of the PRISMA statement (Moher et al.,

2009). More on the search description, selection criteria, and other applications of this statement are discussed in Chapter 2. The results from the literature search are presented in Appendix B.

For the multiple-case study, semi-structured interviews are conducted. For these case studies, the following selection criteria apply:

- The organization under study uses a multi-cloud system as defined in Section 2.3.1.
- A variety of sectors that organizations operate in is under study.
- As laws and regulations may influence multi-cloud arrangements, the organization should be based in Europe.
- The participant from the organization should be (IT) manager or director, CIO, or have a similar function. These people know how their IT landscape is arranged, and how the system works. Therefore, they can add value to this thesis and are able to answer the questions.

For this thesis, four case studies are performed. The interview protocol that is used can be found in Appendix D. These interview questions are tested in a practice interview before conducting the actual interviews, so that the length and continuity of the interviews can be assessed.

The first sub-question, *What are multi-cloud systems?*, is answered by the literature review. This is the first point to focus on, and provides a definition that can be used throughout this thesis. A clear definition also helps in selecting potential interviewees, as well as formulating the right questions.

The three other sub-questions are only partly answered by the literature review. Potential challenges, factors, and requirements are identified by the review, but further confirmed or refuted during the interviews. Some challenges identified in the literature may seem interesting, but if none of the interviewees recognize the challenge in their work, it is probably irrelevant for the framework. In the end, the framework is meant to have both scientific and practical relevance.

When all research questions are answered, the intended framework is derived. This framework is then evaluated. To do this, the controls and mechanisms presented in the framework are assessed by interviewing cloud integration and IT audit experts. This helps in identifying risks and limitations of the framework. The evaluation approach is further described in Chapter 5.

During this research, information is collected in different ways. Besides the data collection methods of formal, recorded interviews and literature search, informal interviews and check-ins also provide information. These informal interviews can be conversations with colleagues, supervisors, or fellow students. Five formal interviews are performed in light of this thesis, of which four are for the multiple-case study and one is for the evaluation. In order to arrange these interviews, over twenty people have been approached to either participate in the interviews or call on their

Activity	Amount
Formal interviews conducted	5
Informal interviews conducted	~ 20
Articles read	~ 80
Other documents read	~ 30
Check-ins	~ 30

Table 1.1: Approximation of work done for this thesis

connections to do so. Furthermore, approximately twenty informal interviews are conducted. Most of these are with experienced colleagues in the field of IT audit. The interviews for the case studies are accompanied by additional information on the particular case provided by the persons who have helped arranging those interviews. An overview of the approximate amount of work done for this thesis is displayed in Table 1.1. Note that many more articles are found, and a lot of these have been skimmed through (see Appendix B). However, the amount of articles that are actually read completely is around 80.

1.5.2 Methodology and instruments

This section describes the theory behind the research methods used in this thesis. In the corresponding chapters, a more detailed explanation of how this theory applies in this context is given. The three parts of this research presented in Figure 1.3 are discussed in a chronological order.

The literature review is executed in line with the PRISMA statement presented by Moher et al. (2009). This means that the search description must be explained in detail, along with inclusion and exclusion criteria. How this applies to this thesis is discussed in Section 2.1. Furthermore, the results of this search are briefly discussed in Appendix B.

The multiple-case study forms the core of the research, where semi-structured interviews act as the main instrument to answer the research questions. The interviews can be designed when all possible factors, requirements, and mechanisms have been deducted from the literature review. The design should act as a structure to guide the interviews, but not determine them. Hence the title 'semi-structured'.

As there is not a large number of companies using multi-cloud systems, the number of case studies is also be small. As described in the previous section, four case studies are performed. The goal of these case studies is to confirm or refute the findings from the literature review.

The case studies need to have validity. Yin (1994) describes four forms of validity: Construct validity, internal validity, external validity, and reliability. Not all of these forms are relevant for this research. In this thesis, internal and external validity are elaborated on.

Internal validity describes the credibility of the information in each case. With interviews, participants can be biased and only share one side of the story. This can be a limitation in the multiple-case study. To overcome this, a triangulation approach is used. This entails that for each case, there are multiple information sources. One of these is the interview conducted with a representative from the organization. Other information sources are colleagues that work for or with the organization, but in an independent role, and documents that are available on the multi-cloud system of the organization. Combining these information sources gives each case internal validity.

External validity describes to what degree the findings from each case study are generalizable. This is approached in two different ways. The first method is replication. By doing multiple cases, it is possible to observe certain patterns. If these patterns match for each case, the multiple-case study has higher external validity. The second method is part of the evaluation of the results of this thesis. For the evaluation, a subject matter expert is interviewed. This person is then explicitly asked if the findings are generalizable. The combination of these two methods provides high external validity to the findings in this thesis.

The results of the interviews are processed by using the guidelines presented by Miles and Huberman (1994). This means that results are classified per theme in an effort for data reduction. These themes are also the baseline of the ultimate framework. Furthermore, the data is displayed by means of a visual model. This provides a solid foundation for the framework, which can then be constructed. After the construction and evaluation, conclusions can be drawn.

During all phases of these interviews, ethical concerns are taken into account. This is done in compliance with the Human Research Ethics policies by TU Delft. This means that an informed consent form will have to be read and signed by participants, and that an adequate data management plan is in place. All formal interviews are held in an online setting. Video and audio of the interviews are recorded in order to transcribe them. The transcripts are pseudo-anonymized to minimize the risk of re-identification. When the thesis is finished, all personal data is deleted. This plan has been approved by the Human Research Ethics Committee of TU Delft.

Chapter 2

Multi-cloud management in theory

This chapter presents the literature review conducted in light of this thesis. The goal of this literature review is to find and analyze literature related to multi-cloud systems, in order to form a theoretical framework for the research. Besides, this review should result in a clear definition of multi-cloud systems. Three directions that are related to the research are explored. To do this, the guidelines from the PRISMA statement are used (Moher et al., 2009). First, the reasoning behind choosing the three directions will be explained.

The first direction focuses on single-cloud management. This sheds a light on factors, requirements, and governance mechanisms that play a role, which may also be relevant in multi-cloud management. This could form the baseline for a proposed framework for multi-cloud management. Besides, this section gives a more thorough understanding of cloud computing and IT management in general.

The second direction is focused on the current state of research on multi-cloud, and also presents a number of technical solutions and frameworks in this area. While the research is performed from an organizational perspective, it is important to gain an understanding of the technical possibilities and bottlenecks in these systems. Besides, initial forms of management may be presented in such studies. This direction will also address the definition of multi-cloud systems.

In multi-cloud systems, organizations involve multiple vendors in a specific part of their IT landscape. Outsourcing IT resources is not new, and a lot of work has already been done in this area. As multi-cloud systems are a form of multivendor outsourcing, it is interesting to study and analyze this work. Therefore, the third and final direction is focused on multisourcing arrangements of IT services.

This chapter is structured as follows. First, the search description and selection criteria are explained. This is followed by the literature review in the directions described above. At the end of this chapter, the conclusions from reviewing the work in these directions are presented. These conclusions are merged into a conceptual framework, which can guide the remainder of this research.

2.1 Search description and selection criteria

This section describes all components of the methods used for this systematic literature review. The PRISMA statement is followed for this purpose (Moher et al., 2009). The three search directions were pre-defined, after consultation with supervisors and an initial exploration of the subject. While search strategies differ on keywords and filters for each direction, selection criteria and information sources are roughly the same for each.

The three main information sources are the databases of Scopus, Web of Science, and Google Scholar. For each of these databases, the same search strings are used for each search. Most searches are limited to the subject areas of Computer Science, Engineering, and Business, Management, and Accounting. Those areas seem most relevant, as cloud computing services are mainly developed by computer engineers, and organizational aspects are sometimes covered from a business perspective. No distinction is made in the type of documents selected for this review. The search is also not limited to a certain time period, as around ninety percent of multi-cloud literature is from 2014 and onward. This can all be relevant for this review. The documentation of the searches can be found in Appendix B.

To make an initial selection in the search results, the titles of the documents are used to assess the relevance of each result. Besides, the number of citations can indicate the authority of a document. Therefore, this is also used in evaluating the results. Afterwards, the abstracts are read to further determine if documents are relevant for this review. The final selection is made by reading through the introduction and conclusion of the remaining documents. Besides the use of search engines, the snowball method is used to find more relevant literature. This means that the references of the selected articles are scanned for other sources that could contribute to this review. The same methods as described in the previous paragraph are used to determine the relevance of these sources too.

The first direction is started by looking at literature on IT management in general. Some literature is already provided by one of the supervisors. From here, the scope is reduced to IT management in the cloud computing context. As the search `"cloud computing" AND (management OR governance)` yields over twenty thousand results, this has to be further refined. Removing the `management` keyword results in much fewer documents. Besides, limiting the search to the subject area of Business, Management, and Accounting also results in a better overview of the available literature. This limitation is justified because this direction focuses solely on a governance and management perspective, and does not take technical solutions from a Computer Science perspective into account. The search was not limited to a certain time period, as the earliest document from the final search term is from 2010. This can still be relevant for this thesis.

For the second section, any literature on multi-cloud can be relevant. Therefore, most searches contain the keywords `multi-cloud` or `multicloud`. Again, the search is limited to the subject are of Business, Management, and Accounting. In order to

find a good definition of multi-cloud, the keywords `terminology OR taxonomy` are added. For the remainder of the search in this direction, keywords like `platform*`, `containerization`, `TOSCA`, and `cloud broker` are used to find relevant information.

The third and final direction focuses on multisourcing IT arrangements. Some literature on this topic is already known to the author, while some other articles are provided by one of the supervisors. Further searches on this topic include the keywords from these articles. Furthermore, theories which are mentioned in these articles are also investigated. These findings can later be used as reference theory for the multi-cloud environment.

During the writing of this review, meetings with supervisors and colleagues provide additional information and input. This results in extra keywords and fields of interest to be applied along the search description presented in this section. The findings of this search strategy are presented in the remainder of this chapter.

2.2 Single-cloud management and governance

This section discusses the literature on single-cloud management. Managing cloud environments is a form of IT management in general. Therefore, IT management is the starting point of this part of the review. From there, the link to cloud management and governance is made.

2.2.1 IT management

Management of IT systems can be distinguished in three types: functional, technical, and application management (Thiadens & Spanjersberg, 2000). Functional management focuses on the use of the system and prescribes *what* has to happen, while application management focuses on *how* this occurs. In reality, this often means that functional management is orchestrating and maintaining the performance of an IT resource, while application management orchestrates and maintains the software behind it. The responsibility of technical management is to maintain the operability of all aspects of the system. In the case of cloud computing, technical management is usually outsourced. When organizations use SaaS, application management is also outsourced. The most relevant form of management for this research is functional management, as this is always on the client's side. Besides, it focuses on the use of the procured cloud services.

The task of technical management is to maintain operability of the system. If this is outsourced, this is the vendor's responsibility. However, in the case of multi-cloud, there is the question of which of the vendors is responsible for the interoperability. Interoperability has already been mentioned in Chapter 1, and is a recurring theme when it comes to challenges around multi-cloud. It has been defined by Wegner (1996) as "the ability of two or more software components to cooperate despite differences in language, interface, and execution platform".

Interoperability can be linked to organizational maturity (Janssen et al., 2014). Organizational maturity refers to the degree to which an organization's IT capabilities compare to its goals, requirements, and benchmarks (Becker et al., 2009). In this thesis, it mostly concerns the way that data is managed. There are different levels of interoperability and different stages of organizational maturity. These are technical, syntactic, semantic, and pragmatic interoperability (Janssen et al., 2014). When all levels of interoperability are supported within an IT system, the organization is fully mature when it comes to that aspect. There is a number of factors that influence interoperability in IT systems. These include the degree of legacy systems in the IT landscape of an organization, the degree of loose coupling between systems, but also data quality, high network performance, and API management play a role. When working with cloud systems, these factors also apply.

Within IT systems, there is a range of managerial factors which can influence the success of an IT outsourcing arrangement, as is the case with cloud computing. Such factors include core competence and stakeholder management (Gottschalk & Solli-Sæther, 2005). This means that the organization needs a clear definition of their IT needs and competences in order to decide what they will outsource. Besides, organizations need to establish effective communication between all stakeholders. Another factor which is often mentioned in the literature is top management support. Most of the factors that influence decision-making and performance in traditional IT outsourcing environments are still valid in the cloud computing context (Schneider & Sunyaev, 2016). Core competence management can be important when deciding on how to achieve business level objectives (BLO), as organizations require a broad understanding of what is needed to do this (Sedaghat et al., 2011). This traces back to functional and application management of IT systems, where the what and how questions are also important. Other relevant factors presented by Sedaghat et al. (2011) are trust, risk, and efficiency. However, these factors are often difficult to quantify.

It is clear that there is a variety of factors that influence the quality of IT management. Some of these factors are not relevant in the cloud computing context, while others go beyond the scope of this research. Still, this overview provides a clear picture of the complexities created by the many factors in IT management. The next section is focused on how this appears in the cloud computing context. This includes both management and governance in the cloud, and will also further describe general IT management aspects which are relevant to cloud computing.

2.2.2 Governing the cloud

Cloud management and governance are interrelated on multiple levels (Fortis & Munteanu, 2014). Therefore, it is interesting to look at the combination of both concepts. The difference between governance and management in this context is that governance focuses on the structure and positioning of IT within an organization, while management is more about the operational activities (Peterson, 2004). In this sense, management follows the structure dictated by governance. Therefore, this sec-

tion will first describe cloud governance, followed by managerial considerations that follow from it.

Cloud governance

According to Weill and Ross (2005), effective mechanisms in IT governance are decision-making structures, alignment processes, and formal communications. This means that when designing IT governance, the division of roles, accountability, and the clarity of communications are essential. Besides, they argue that IT governance should enable behavior that is consistent with business level objectives. Consistency and alignment are recurring themes in cloud governance, which will also be shown in the following paragraphs. In cloud computing, accountability is also a component of trust (Ko et al., 2011). The importance of trust and its relation to governance are further specified in Section 2.4.2.

Prasad et al. (2014) propose multiple governance structures and mechanisms for the cloud computing environment. These contain a chief cloud officer, a cloud management committee, a cloud service facilitation centre, and a cloud relationship centre. These mechanisms should contribute to achieving cloud-related business objectives. Other suggestions for a governance structure contain collaborative board oversight and a continuous audit program (Prasad & Green, 2015). Besides, the authors (2014) identify three levels of governance:

- *Business governance* describes the way that cloud services are used and managed by and within the organization.
- *Technical governance* is related to the technology side of cloud computing. For instance, this focuses on the architecture for the orchestration of cloud services, along with technical requirements.
- *Service governance* deals with monitoring and tracking aspects of cloud computing. Thus, checking if procured services work as they are supposed to.

However, it can be argued that one servers the other. Governance on the technical and service level are elements of cloud usage and management, and thus of the overall business governance. Still, governance on these levels should be aligned in order to achieve the business level objectives. Other governance types and how these are defined in this thesis are further described in Section 2.4.2.

In this thesis, the effectiveness of management is assessed by determining if the desired functionality of a system is achieved. This is similar to using asset utilization as a performance metric, which can influence the governing style of an organization. From this perspective, a powerful governance mechanism is the use of SLAs (Weill & Ross, 2005). In the cloud computing context, these are often complemented by Quality of Service (QoS) requirements (Wu et al., 2011). From a managerial perspective, this can be useful in monitoring cloud performance. This is related to the requirements of cloud resource provisioning, configuration, and deployment. Monitoring cloud performance can have multiple purposes. First, it can be used to determine if the business

objectives are achieved. That means that the desired functionality of the cloud system is attained, which is a major determinant for the effectiveness of management in this thesis (see Section 1.4). Another use of monitoring cloud performance is to assess risk and realize adequate controls to mitigate them. Risks in cloud computing can arise in identity and access management, data management, infrastructure security, and other areas (Deloitte, 2019). To mitigate such risks, there exists a variety of IT governance and control frameworks. These include COBIT, ITIL, and ISO standards. A comparison of these frameworks in the cloud computing context shows that there is much room for improvement in cloud governance (Becker & Bailey, 2014). Still, these IT governance frameworks provide a solid foundation for risk assessment in the cloud.

This foundation is used by Bounagui et al. (2019), who work towards integrating these models to create a comprehensive governance framework for cloud computing. They have a clear understanding of the scope and features of the three frameworks mentioned before, and identify governance requirements on the aspects of information security, cloud migration, risk management, and SLAs. While this is a relatively new framework which is still in development, it may have impact on both cloud governance and management. The next section will further discuss the managerial side of cloud computing, starting with the relevance of the ITIL framework. COBIT and ISO standards are not addressed in more detail, as they have a focus on IT governance and information security, respectively. IT governance has already been discussed in this section, and while information security is an important requirement in cloud computing governance, its details are beyond the scope of this thesis.

Cloud management

ITIL is one of the most recognized frameworks for IT service management. It provides a range of best practices on multiple aspects, and has a proven effectiveness (Potgieter et al., 2005). However, one can ask if ITIL is still relevant in a cloud computing environment. It seems that this framework requires some adjustments in order to be effective for cloud computing (Heininger, 2012). Besides, Heininger (2012) argues that classic IT service roles are not yet clear in this context. These claims are substantiated by Al Mourad and Hussain (2014), who also address the importance of business relationship management. Still, these authors recognize the potential value that an extension of the existing ITIL framework could have for the cloud. It seems like classical IT management still occurs in the cloud computing context, but a part of it is outsourced. This means that ITIL components end up at different parties, which could result in the unclear division of roles described by Heininger (2012). The IT service life cycle as described by ITIL can also be translated to a cloud service life cycle (Karkošková, 2018). This is a further sign that such a framework can be used as a foundation for cloud service management. The majority of studies on the relevance and applicability of ITIL in the cloud computing context considers ITIL v3, which was introduced in 2007. In 2019, ITIL 4 was introduced, which may have a larger focus on the modern standard of cloud computing. However, there is no research on this

topic yet available due to the novelty of this framework.

Besides the use of frameworks like ITIL, there exist other approaches to IT services management. One of these is the use of a Service-Oriented Architecture (SOA) (Bardhan et al., 2010). A SOA allows loose coupling in the system, which can be a beneficial factor in cloud management. Besides, service-oriented computing and cloud computing have much overlap, so one would say that these are intertwined on multiple levels (Wei & Blake, 2010). However, a SOA focuses on the internal side of an organization, while cloud computing goes beyond these borders and involves multiple parties (Erbes et al., 2012). Once again, traditional roles are changed and unclear in the new cloud computing environment. The question on how to deal with these models and frameworks in the cloud context remains.

Sun et al. (2010) introduce an architecture model for managing and monitoring cloud services. This model is based on a number of interesting concepts. Some components are based on ITIL, but the concepts of a service broker and a traditional Enterprise Service Bus (ESB) are also incorporated in the model. These entities can be useful as they provide a way of selecting and managing cloud services. This role can also be described as an integrator (Erbes et al., 2012).

The literature discussed in the previous paragraphs shows that cloud management does indeed have a lot of overlap with traditional and general IT management. Still, it requires some adjustments. As roles are uncertain in the cloud environment, these should be clearly defined and divided, as has been addressed by multiple IT governance frameworks. Where this section has focused on simpler forms of cloud computing, the next section will discuss literature on multi-cloud.

2.3 Multi-cloud techniques and technologies

In the literature on multi-cloud systems, two main themes are identified. One of those is the use of standards to improve the interoperability of cloud applications. Other studies focus on creating technical frameworks for multi-cloud computing, along with certain techniques for deciding on cloud providers. The first part of this section provides a clear definition of what multi-cloud systems are. The section that follows describes the literature on standardization, while the third part discusses the frameworks. The final section addresses existing literature on multi-cloud management and remaining challenges in that area.

2.3.1 Defining multi-cloud systems

The use of multiple clouds has many names; multi-cloud, hybrid cloud, aggregated cloud, cross-cloud, to name only a few. Some of these names have overlap, but others imply different things. To avoid confusion, this section aims to specify what is meant by multi-cloud systems in this thesis.

Petcu (2013) brings some clarity in the jumble of names. She considers two main

models in the use of multiple clouds: Multi-cloud and federated cloud. The difference between them is that in a federated cloud environment, there are prior agreements to share resources between the cloud providers. This often involves a cloud broker, whose role will be further described in Section 2.3.3. In contrast to federated cloud environments, multi-cloud implies an environment where there are no such agreements. In this case, the client uses multiple independent public clouds. Petcu further argues that federated cloud is preferred by cloud providers, while clients favour the multi-cloud environment. Motivations behind this are mostly cost efficiency and enhancement of service offerings.

In a federated model, the client is not always aware that they use services from different cloud providers (Petcu, 2014). Grozev and Buyya (2014) classify multi-cloud as a form of inter-cloud, but also emphasize the independence of the cloud providers. This means that in multi-cloud, collaboration between cloud providers is not voluntary. This intersects with the concept of forced coopetition (Wiener & Saunders, 2014), which will be discussed in Section 2.4.2. Toosi et al. (2014) also link multi-cloud to inter-cloud. Besides, they argue that in a multi-cloud system, there should be a form of cloud integration. This can consist of standard interfaces, a cloud broker, or certain middleware. These possibilities will be further discussed in the following sections.

From the various sources described above, it is clear that multi-cloud entails the use of multiple independent public clouds from different cloud providers. The question remains how these clouds are used and orchestrated. Ferry et al. (2013) describe multi-cloud as applications using services from multiple private, public, or hybrid clouds. This is often called a service-based approach (Samreen et al., 2014). However, there also exists a library-based approach. With library-based multi-cloud, a number of cloud applications from different providers can be accessed through one unified API (Alqahtani & Sant, 2016). This can be useful when an organization operates in a fragmented IT landscape, where it can be difficult for the end user to navigate the variety of applications. The differences between these uses of multi-cloud are displayed in Figure 2.1. Cloud services and cloud applications are procured from different providers. The dotted arrows represent possible connections between the cloud services.

2.3.2 Standardization in cloud environments

As described in the introduction, problems like vendor lock-in are often caused by a lack of standardization. To mitigate this, standards like TOSCA (Topology and Orchestration Specification for Cloud Applications) and CAMP (Cloud Application Management for Platforms) were introduced. These standards can be used to create compatible cloud applications and services. TOSCA prescribes how to orchestrate cloud applications in a way that they are less dependent on the underlying infrastructure (OASIS, 2013). This increases portability and interoperability of cloud applications. CAMP is meant to standardize APIs in the PaaS context. This standard can be used to specify specific needs from the client side (OASIS, n.d.). A number of studies investi-

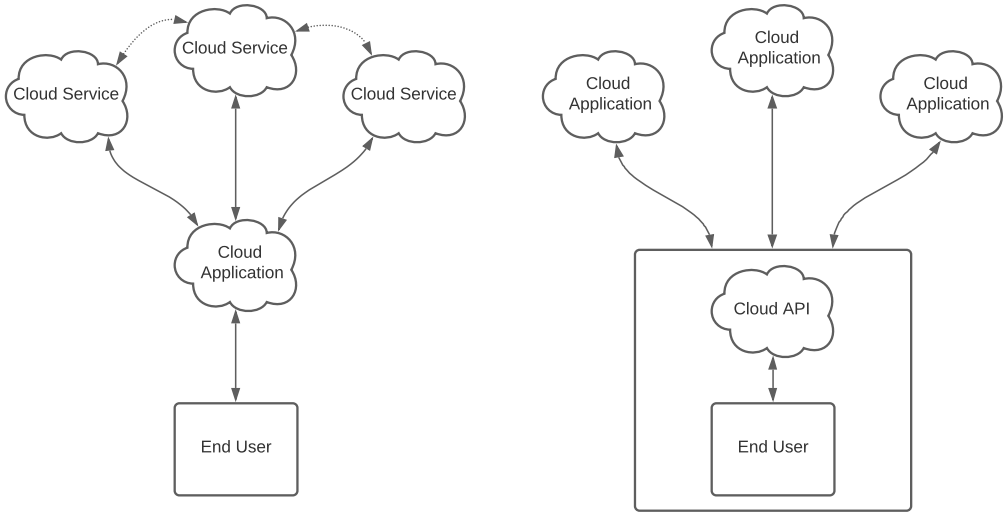

Figure 2.1: Service-based (left) and library-based (right) multi-cloud

gates the technical possibilities of these standards.

While such standards are good options for topology specifications and application orchestration, it is argued that managing such applications is too complex (Carrasco et al., 2014). Some scholars propose to combine the two standards and use the benefits of both (Carrasco et al., 2014; Alexander et al., 2017). Both studies present an architectural design to integrate the two standards. The work by Alexander et al. (2017) is a bit more elaborate. They extend the CAMP standard to a platform in order to provide possibilities for application management, from a technical perspective. Still, the authors argue that their proposed platform does not yet support all documents and policies. Besides, the standards are not optimal for supporting heterogeneous cloud environments (Carrasco et al., 2014).

Other studies focus on the use of only the TOSCA standard. Caballer et al. (2018) and Tricomi et al. (2017) use the OpenStack platform as middleware for their proposed solutions. This is an open source cloud infrastructure, providing components for orchestration, virtual machines, containers, and other services. Similar to Carrasco et al. (2014), Caballer et al. (2018) argue that the orchestration of IaaS services in a multi-cloud environment is often very complex and beyond the expertise of most users. Therefore, these users should be provided with PaaS or SaaS resources to avoid the complexity, and be presented an unified interface.

2.3.3 Multi-cloud frameworks and techniques

There exists a range of frameworks for the platforms behind such unified interfaces, like SeaClouds (Brogi et al., 2016), Cloud4SOA (Kamateri et al., 2013), which combines multi-cloud and SOAs (see Section 2.2.2), and many others. Tomarchio et al. (2020) present a systematic review of a number of these frameworks. The authors

make a distinction between multi-cloud and cross-cloud support, arguing that the first focuses on making the platform work with multiple cloud providers' APIs, while the latter allows for orchestrating a single application over multiple clouds. One of their conclusions is that standard models are not yet sufficient, and that this should be further enhanced in the future. Besides, the authors encourage to further explore the possibilities of model re-usability and containerization. This should result in increasing the options for cloud migration, deployment, and management.

Other approaches to create solutions ready for multi-cloud environments describe the use of cloud brokers (Tricomi et al., 2017) and standardized applications (Guillén et al., 2013). Cloud brokerage entails the concept of an entity (the broker) to negotiate the relations between cloud providers and consumers, and find the best fit between them. Standardization of applications means developing them in such a way that they are compatible with the services of multiple cloud providers. This enhances application portability, and is further supported by containerization. Containers make it possible to create an abstraction of application components, thus increasing their interoperability. They are recognized to have great potential to advance multi-cloud technology (Pahl, 2015). Still, a multi-cloud platform with a unified interface remains the most viable solution, as it requires less technical knowledge of the user and could provide an organized overview of cloud services and their use. Besides, the capabilities of such a platform could also support the use of containers and cloud brokers. Some of the existing platforms have been reviewed by Kritikos et al. (2020). The framework they have created for this purpose could be useful for organizations to assess potential platform providers.

Another work by Kritikos and Plexousakis (2015) discusses the challenges of cloud service composition. This also addresses the question of which cloud provider to choose for which service. Their method uses both functional and QoS requirements, and the composition is approached as a constraint problem. The final composition of cloud services is important for how multi-cloud applications are arranged. This is related to multisourcing theories, which will be discussed in the Section 2.4.

2.3.4 Multi-cloud management

Despite all these technical solutions, there is still a range of managerial challenges that remain. That is also the main reason for writing this thesis. This section focuses on the available literature on this topic. First, possible methodology on managing multi-cloud systems will be discussed. This is followed by literature on remaining challenges in this environment.

Alpar and Polyviou (2017) argue that coordination agreements in multisourcing and multi-cloud are similar. The possible link between multivendor outsourcing and multi-cloud has already been made in the introduction of this chapter, and is thus further confirmed by this study. The study presents two coordination modes for management: Direct and mediated. The difference with traditional multisourcing is that mediated coordination in the multi-cloud context is executed by a third party, instead

of one of the vendors. Both forms of coordination can be applied by using a multi-cloud management platform (Kritikos et al., 2019). Such a platform can use a variety of existing integration methods. One of the presented methods is the use of an ESB, which has been addressed before in Section 2.2.2. According to Kritikos et al. (2019), this is closely related to Enterprise Application Integration (EAI). Another factor that is mentioned in Section 2.2.2 is trust. Fan and Perros (2014) present a framework for trust management in the multi-cloud environment. They mention trust service providers, who have tasks like SLA negotiation and monitoring. This may be seen as a form of mediated coordination.

While these methods provide a useful foundation for managing multiple clouds, they do not eliminate all challenges. For instance, in multi-cloud environments, it can be difficult for low-level management to determine what their actions need to be in order to fulfill high-level goals (Elmroth et al., 2011). Besides, security and privacy remain a delicate topic when combining multiple systems (Akande et al., 2013). From this perspective, it can for example be hard to implement a reliable system for identity access management in an integrated system like multi-cloud. Furthermore, interoperability is a crucial factor in the multi-cloud context (Ardagna, 2015).

Looking at the separate issues and possible methods for managing multi-cloud, one can say that the overarching challenge is integration. Within this challenge, security, privacy, access management, and interoperability can all be seen as factors contributing to a successful integration. Along with choosing the right coordination mode and a fitting integration method, effective management may be achieved. Then, the question is how to approach this. The next section focuses on existing theories on IT multisourcing, which could provide guidance as reference theory for integration of multiple clouds.

2.4 Multisourcing arrangements of IT services

This section presents a brief history of the evolution of IT outsourcing, along with a definition of what multisourcing IT arrangements are. This is followed by a review of literature on governance structures in such arrangements. The section is concluded by a discussion on relevant theory for this thesis.

2.4.1 The evolution of IT outsourcing

The outsourcing of IT capabilities has been around since the 1960s. Cloud computing was a shift in IT outsourcing, changing the way that organizations procure and use IT services (Dhar, 2012). Lee et al. (2003) present a model of the evolution and steps taken in IT outsourcing arrangements. This model ranges from the 'make or buy' decision to the forming of partnerships. Choosing to use multiple vendors falls between the stages of defining the scope of outsourcing and determining the performance of the service. According to the authors, the driving theory between these stages is Coordination Theory. Coordination can be defined as "the process of

managing dependencies between activities" (Malone & Crowston, 1994, p. 90). Coordination Theory acts as a set of principles on how to orchestrate this process (Malone & Crowston, 1990). This is especially important when deciding how to orchestrate cloud arrangements with multiple vendors. Such arrangements are also called multisourcing arrangements or multivendor outsourcing arrangements. Multisourcing IT arrangements can be addressed from both the client's as well as the vendor's perspective. When managing multi-cloud systems, it is important to be aware of both.

Bapna et al. (2010) are one of the first to address the change from original dyadic relationships in IT outsourcing to the nuanced field of multisourcing. They argue that relational governance mechanisms in these arrangements depend on interdependence between the activities and actors, among other factors. Besides, vendors should cooperate by enabling the other vendors to fulfill their part of the arrangement. This suggestion is further substantiated by other studies, which will be discussed later in this section. One way to approach this is by using Operational Level Agreements (OLAs). Another way of achieving the right coordination is by use of the guardian vendor model. In this model, the guardian vendor assists the client in creating and maintaining the architecture of the IT arrangement (Oshri et al., 2019). Other scholars have an altered view on this, and argue that the guardian vendor has a mediating role, and monitors other vendors (Wiener & Saunders, 2014; Bapna et al., 2010). A commonality in these cases is that the guardian vendor helps the client with its governance structure by compensating for certain knowledge gaps.

2.4.2 Governance types and mechanisms in multisourcing

Because there are much interdependencies between actors, it is essential to have a rigid governance structure in place when managing multisourcing IT arrangements. There are three types of governance that can be distinguished in these scenarios (Plugge & Janssen, 2014):

- *Inter-organizational governance* describes the way that the arrangement is designed in terms of roles and positions that the vendors have. A detailed structure should result in clear communication, and can be achieved by creating a strategic plan with long-term vision. Mechanisms to support this are SLAs between client and vendors, and OLAs between the vendors themselves.
- Findings on *contractual governance* show that clients are often predominantly focused on financial benefits instead of long-term gain of an arrangement, due to the lack of a strategic plan.
- This is also reflected in *relational governance*, which covers the relationships between client and vendors. Due to the short-term mindset, these are often neglected. A neglected relationship with no prospect of improvement can result in a lack of trust, which can hurt performance in such arrangements (Sabherwal, 1999).

While relational and contractual governance may be self-explanatory to some ex-

tent, inter-organizational governance brings the most complexity in the overall structure. This may either be approached with standardization, contracts, and agreements, or in a manner that is more trust-based. Usually, the arrangement will be a combination of both. In this line of thought, both contractual and relational governance are elements of the overall inter-organizational governance. However, the main goal is still to deal with the complexity and possibly reduce it. The remainder of this section will discuss how multisourcing theory approaches this complexity and associated challenges.

Working with multiple vendors can lead to tensions and disputes. In order to manage these, it is important to understand how collaboration occurs in multisourcing arrangements, and how such tensions emerge. A Social Exchange Theory perspective shows that actors in a multisourcing arrangement attempt to balance the elements of the exchange with other actors (Plugge & Bouwman, 2015). However, strategic interests can hinder this exchange, as actors tempt to compete instead of collaborate. Again, it is argued that parties in multisourcing arrangements opt for clear control mechanisms to mitigate and manage expectations and agreements. Another way of increasing collaboration between actors is by creating common value. However, there are tensions which can stand in the way of this process. Plugge and Bouwman (2018) emphasize the importance of clear inter-organizational, relational, and contractual governance to overcome these barriers. Besides, they suggest that boundary spanners should be included for knowledge transfer within the multivendor ecosystem. However, one can ask when these types of governance are clear. This question correlates with the problem described in Section 1.2, and further accentuates the need for a means to cope with it.

Wiener and Saunders (2014) present three models for multisourcing IT arrangements, which can be found in Figure 2.2. The mediated model is similar to the guardian vendor model discussed earlier in this section. In the direct model, the client arranges the governance structure themselves, and manages the arrangement without any help. In these models, vendor competition and cooperation are low to moderate. The vendors operate in separate areas, and cooperation with other vendors is at a superficial level. However, in the direct-overlapping model, the vendors have overlapping operating areas and have to cooperate at deeper levels. This causes both competition and cooperation to be high, creating so-called forced coopetition.

Another model to describe the multisourcing environment is the partnership-oriented model. It is related to the direct-overlapping model, but has a lower degree of competitiveness (Schmidt & Suomi, 2018). It is partly based on an allocation of tasks between the vendors, which is a competitive process in the beginning, but can last for a longer period of time afterwards. This can be beneficial to collaboration, and also strengthen relationships between client and vendors. Recalling the study by Plugge and Bouwman (2015), this can create more willingness between vendors to exchange information to further increase collaboration.

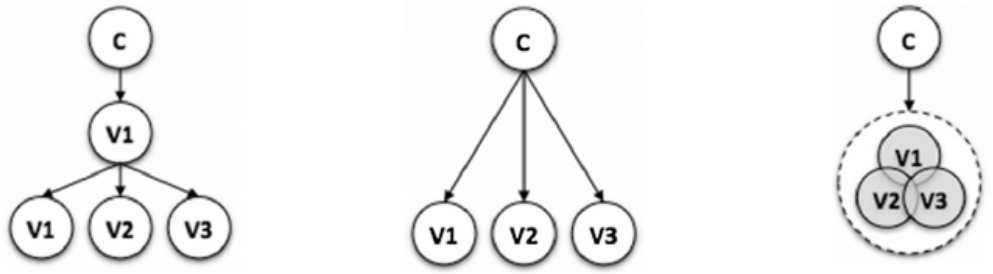

Figure 2.2: Three IT multisourcing models. From left to right: mediated, direct, and direct-overlapping (Wiener & Saunders, 2014)

2.4.3 Coordination Theory in multisourcing

Section 2.4.1 discussed the evolution of IT outsourcing, and found that Coordination Theory is relevant in the multisourcing context. The work by Lee et al. (2003) described this as the driving theory when the scope of an outsourcing arrangement is determined. Coordination Theory can be useful for investigating the interdependencies between actors in the multisourcing environment. The previous section showed that these interdependencies constitute a large challenge, following from the complexities of inter-organizational governance. Therefore, this theory is preferred over other relevant theories, like Resource-Based, Social Exchange, or Transaction Cost Theory. A joint perspective of these theories may provide broader insights, but is beyond the scope of this thesis.

Coordination in multisourcing has been studied by a number of scholars. Plugge and Janssen (2014) use Coordination Theory to investigate how dependencies are managed in multivendor IT outsourcing arrangements. Their findings show a lack of coordination in the arrangement under study, caused by the client basing their activities on traditional dyadic relationships. This is in contrast with the polyadic relationships in the multisourcing context, especially in the forced coopetition model presented by Wiener and Saunders (2014) (See Figure 2.2).

Inter-organizational coordination in IT service management can be performed on the SLA level (Edgington et al., 2010). This in line with the work by Alpar and Polyviou (2017) on coordination in a multi-cloud environment, which is discussed in Section 2.3.4. These authors suggest to use integrated SLAs and OLAs to improve collaboration in the multisourcing environment. However, this only addresses the element of contractual governance, but leaves the question of how to deal with and coordinate relational aspects. IT outsourcing relationships are build on mutual trust, interdependece, and commitment (Ali et al., 2017; Rhodes et al., 2016). Building trust, and therefore building relationships, takes time. This is important to keep in mind when coordinating multisourcing arrangements.

2.5 Conclusions

This literature review was performed to explore the different concepts and theories that are useful in the context of this research. This entailed three directions: literature on single-cloud management, multi-cloud technologies, and multisourcing IT arrangements. One of the goals of this review was to provide a definition of multi-cloud systems. Furthermore, the review was aimed at identifying possible relevant factors, requirements, and challenges. The findings of this review reveal the intricate complexities of governing cloud and multisourcing arrangements, and substantiate the knowledge gap and problem described in the introduction of this thesis. This section is split into three parts. First, the findings from the literature review are discussed. Second, these findings are merged into a conceptual framework which can provide guidance for the remainder of this research. The final part of this section addresses how this conceptual framework is used in the remainder of this thesis, and how it applies in the analysis of a practical setting.

2.5.1 Findings

Many studies have been performed to investigate IT management in general. There exist different types of management in this context: Functional, technical, and application management. In the cloud computing context, technical management is almost always outsourced. This covers the operability of the system. In the case of multi-cloud, interoperability is a recurring factor and challenge. If operability is outsourced, this raises the question which party in the system holds responsibility and accountability for interoperability. This may be a bottleneck in multi-cloud configurations.

Cloud management and governance are intertwined, with management often following from the dictated governance structure. In this context, three types of governance are identified: business, technical, and service level governance. However, it is concluded that business governance is conducted on the technical and service level, so these are elements of one another. Other relevant factors include a clear division of roles, business level objectives, and risk management. There exists a range of IT management and governance frameworks, like ITIL and COBIT, which provide a solid foundation for governing the cloud. These can be combined with concepts like SOA or ESB to manage cloud services.

Multi-cloud systems are defined as systems where multiple independent cloud services are used in one environment. This can be either service-based or library-based. In a service-based multi-cloud system, a number of services by different cloud providers is used for one application. In a library-based system, multiple cloud applications are combined by one unified interface or certain middleware.

Literature on multi-cloud technologies showed that there exists an array of multi-cloud frameworks. A commonality which can be derived is that there is still a lack of standardization. This works on multiple levels. From the technical side, cloud services

Factors		**Mechanisms**
Inter-organizational governance	Contractual governance	SLA OLA Audit program
	Relational governance	Decision-making structures Cloud Office
Business governance	Technical level (including interoperability)	IT Frameworks Middleware SOA Standardization OLA
	Service level	SLA BLOs Decision-making structures Cloud Office

Table 2.1: Overview of factors in multi-cloud management and corresponding mechanisms

are not compatible due to their configuration. From an organizational perspective, it is more difficult to create substantiated SLAs. This is also what the initial problem described, as can be read in the introduction of this thesis. From a managerial perspective, there is a clear distinction between direct and mediated management. The overarching challenge in this context is integration.

Multisourcing IT arrangements have been around for a while. Dyadic relationships have evolved into a nuanced field with multiple stakeholders. Again, a mediating role is suggested to assist organizations with governance and management. Still, different types of governance play a large role in multisourcing arrangements: Inter-organizational, contractual, and relational governance are of importance. In this context, contractual and relational governance are elements of inter-organizational governance. To direct the governance, it is essential to identify which type of arrangement is set up. Three models for this are shown in Figure 2.2.

The literature indicates that Coordination Theory can be helpful in this context. Still, this needs to be complemented by relational aspects in the governance structure. Together, this may result in an effective method to deal with interdependencies in a multi-cloud system. Besides, multi-cloud management should minimize complexity in the environment, in order to ensure optimal integration of services.

One of the goals of this literature review was to explore potential factors and mechanisms in multi-cloud management. All identified factors and mechanisms are discussed in Appendix C. A simplified overview of these factors is displayed in Table 2.1. This also provides a start for the conceptual framework, which is discussed in the next section. In that framework, these factors are shown, along with which other factors they influence or are a part of.

The conceptual model is ultimately meant to summarize the findings from this chapter. Besides, it provides a guideline for the multiple-case study in the next chapter. There, the conceptual framework is used to see how the theory on multi-cloud

management applies in a practical setting. In the end, the results from both of these chapters form the foundation of the framework for effective multi-cloud management.

2.5.2 Conceptual framework

The findings from the previous section can be merged into a conceptual framework. This visualizes how the different concepts from multisourcing theory and cloud management link to each other. In the end, this framework should provide guidance for the remainder of this research. The conceptual framework can be found in Figure 2.3.

The goal of this thesis is to build a governance and management framework for effective use of multi-cloud. This is done by identifying factors, challenges, and means to mitigate them. The overarching challenge that is deducted from the literature review is integration. This is combined with another crucial factor: Coordination. Together, they form the pillars of effective multi-cloud management.

Management is often dictated by the governance structure, as has been found in Section 2.2.2. Therefore, governance is crucial in the conceptual framework. Different types and levels of governance have been identified in this chapter. Prominent forms of governance in the multisourcing context are inter-organizational, contractual, and relational governance, with the latter two being elements of the first. Together, they influence multi-cloud management from an inter-organizational perspective. However, there is also an intra-organizational perspective, constituting the governance within the organization instead of that with other stakeholders. In this thesis, this is called the business governance, which is described in Section 2.2.2.

Two elements of business governance have been identified: Service level and technical level governance. Therefore, these two elements constitute the business governance, which is mostly similar to intra-organizational governance, and is a second major factor in effective multi-cloud management. The different forms of IT management discussed in Section 2.2.1 are included in this conceptual model under the business governance. While functional management focuses on the service to the end user, technical management is clearly an element of technical level governance. Application management is a bit of both, and is therefore connected to both in the framework.

For all these types of governance, there exist certain mechanisms to support them and implement them into an organizational structure. A few of those are visible in the conceptual framework. A full list of the different factors, including the governance types, and corresponding mechanisms are displayed in Table C.1 in Appendix C. A comprehensive overview of factors from the conceptual model and corresponding mechanisms is shown in Table 2.1. The reasoning behind this table is explained in Appendix C.

Besides governance, the context of the multi-cloud environment also plays a role in managing it. This entails the type of multisourcing arrangement that an organiza-

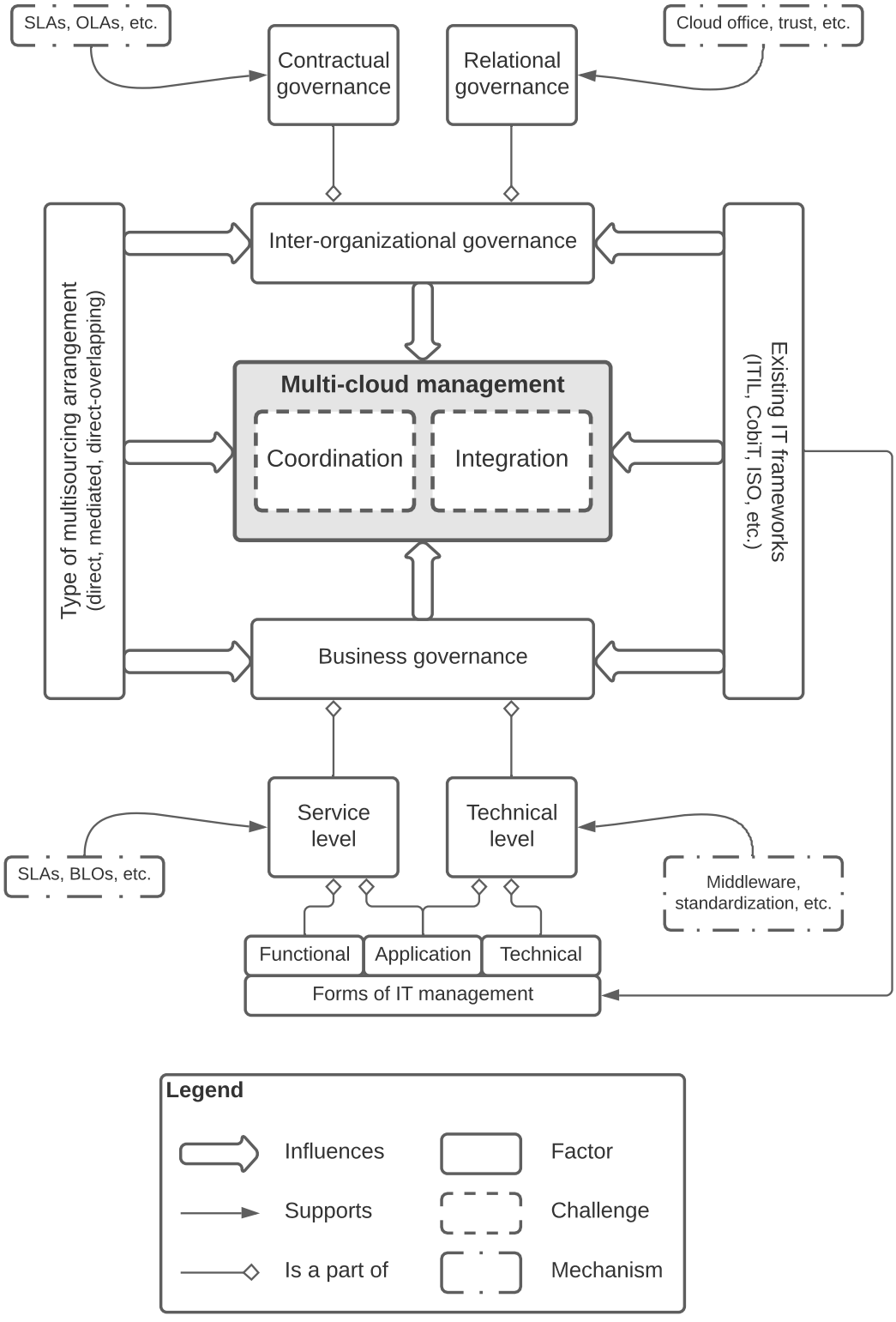

Figure 2.3: Conceptual model of theory on multi-cloud management

tion is in. In turn, this also influences the governance structure of the organization. There can be a big difference in inter-organizational governance between a mediated arrangement and a direct-overlapping arrangement. This is different for each organization, and should be aligned with their business level objectives.

A final addition to this conceptual framework are the existing IT governance and management frameworks. These frameworks provide rules and guidelines, of which a lot are also applicable in the multi-cloud context. From a managerial perspective, it is important to identify which of these guidelines are useful in a particular case, and should again be aligned with the organization's objectives.

This conceptual framework creates a comprehensive overview of how all concepts and factors deducted from the literature review come together. The goal for the remainder of this thesis is to investigate how this looks in the practical context, and compare and analyze those findings with this conceptual model. Then, this can be translated to a practical framework for effective multi-cloud management.

2.5.3 Theory versus practice; the conceptual framework applied

The conceptual model that is presented in Figure 2.3 and explained in the previous section covers all aspects of the theory discussed in this chapter. Besides, it gives preliminary answers to the research questions formulated in Section 1.4. These research questions consider challenges, factors, and requirements. With the multiple-case study, these concepts are studied in a practical context.

Challenges

The conceptual model shows the overarching challenges of integration and coordination in multi-cloud management. These challenges can be decomposed into smaller ones, like interoperability, security, and privacy. The size and presence of these challenges depends on the type of arrangement and the way that the governance structure is set up. The multiple-case study should show if these challenges indeed occur, and how organizations deal with them.

Factors

There is a variety of factors shown in the conceptual model. A comprehensive list of all identified factors is discussed in Appendix C, of which a simplified overview is given in Table 2.1. The next chapter shows how these factors appear in a practical context. The conceptual model also shows a number of relations between the different factors. These relations are also assessed by means of the multiple-case study.

Requirements

The fourth sub question considers the requirements for effective multi-cloud management. That entails the requirements for optimal use of the different cloud services,

also describes as a high degree of asset utilization. Furthermore, it entails what is required to overcome the challenges described before. These requirements are not immediately clear from the conceptual model, but follow from the factors and challenges it describes. For instance, requirements for effective governance and management in a multi-cloud system could be loose coupling or a clear division of roles. This overlaps with certain identified mechanisms, like the presence of a cloud office, middleware, and BLOs. In the next chapter, such requirements are further investigated. A practical perspective on these theoretical requirements helps in developing the framework in Chapter 4.

A final note

The conceptual framework provides guidance for the remainder of this thesis and shows how the identified concepts from the literature review come together. It also shows a number of mechanisms, which are displayed in Table 2.1 as well. These mechanisms are important to approach the identified factors in a way that supports effective multi-cloud management. In the end, this is the main goal of this thesis.

The next chapter describes how these theoretical concepts apply in a practical setting. This includes the challenges, factors, and requirements discussed in this chapter, but also the mechanisms and how they can be applied. This provides insights in which mechanisms are present and required in cases with effective multi-cloud management. These findings are then grouped together, and form the foundation of the governance and management framework. With that framework, the identified challenges can be overcome.

Chapter 3

A practical perspective

This chapter discusses the multiple-case study and the interviews that were performed as method for this purpose. It is structured as follows. First, the goals of the multiple-case study are addressed. This considers why the interviews are useful, how they contribute to this research, and what information they should provide. These goals are a logical consequence from the previous chapter. This way, the theory discussed in the previous chapter is tested in a practical setting.

Second, each case is analyzed based on the conceptual framework in Figure 2.3. A short summary of the case is given, along with notable points. The goals stated in Section 3.1 are addressed, along with how the interview for the particular case has contributed to achieving those goals.

In the third section, the cases are compared to each other. Commonalities and differences are analyzed, and certain patterns are further discussed. Besides, this section links back to the literature review to see how theory on multi-cloud and multisourcing comes back in a practical setting. The results of these interviews should identify good practices and how to handle certain challenges. These results can then be used to create a framework on coordination of cloud services in the next chapter. The interview protocol for these interviews can be found in Appendix D.

The fourth part of this chapter discusses the validation of the multiple-case study. This includes both internal and external validation, as described in Section 1.5.2. The validation is executed in accordance with the work by Yin (1994).

This chapter is concluded with the findings of the cases addressed in this chapter. These are also compared with the findings from the literature review. Together, they form the foundation of the framework presented in Chapter 4.

3.1 Goals of the multiple-case study

This section addresses the goals of the multiple-case study. The interviews are used as a method for gathering data in light of multiple small case studies. Each case is analyzed according to the conceptual framework presented in the literature review. Besides, the analysis traces back to the initial research questions formulated in Section 1.4. A subsection is devoted to each of the research questions 2 to 4. This means that the first part of this section focuses on challenges in managing multi-cloud, the second part on factors, and the third part on requirements that follow from the other two parts. This is similar to the structure in Section 2.5.3, and shows the link with the conceptual framework from the previous chapter.

3.1.1 Challenges

In Chapter 2, a number of potential challenges in multi-cloud management were identified. The overarching challenge is integration, but this consists of multiple elements. These are elements like coordination, interoperability, security, and privacy. Specific challenges to overcome in these areas can be data management or identity and access management. This is also dependent on the type of multisourcing arrangement, so it can be different for each organization. Still, it always seems to trace back to integration.

The interviews conducted in light of this research should either confirm or refute these challenges. Besides, participants have the possibility and are encouraged to share the specific struggles that their organization has had when managing a multi-cloud system. This may bring up additional challenges that were not initially identified in the literature review. The participants will also be asked how they deal with these challenges, in order to identify mechanisms that are useful in multi-cloud management. In this scenario, interviews are useful because the participants have practical experience with elements that are, up until this point, only discussed theoretically.

This should result in an initial overview of challenges and potential mechanisms to mitigate them. Along with the literature review, this provides an answer to research question 2. This answer is evaluated in Chapter 5.

3.1.2 Factors

The approach to confirming and refuting relevant factors is similar to the approach discussed in the previous section. The literature review resulted in an extensive list of potential factors, which are discussed in more detail in Appendix C. Some of these factors overlap with certain challenges. For instance, interoperability is a challenge, but also a crucial factor in multi-cloud management. Most factors can be grouped under either inter-organizational governance, or under business governance. The latter is also intertwined with traditional IT management. Other factors include the type of multisourcing arrangement and organizational maturity.

However, asking about relevant factors is a difficult question to answer for participants. Therefore, the questions on these factors are divided in the same way as in Table 2.1. One section of the interview focuses on governance, especially on inter-organizational governance, in the multi-cloud context. Another section focuses more on the business governance, and the forms of management that accompany this. The questions focus on how these types of governance are arranged in the case under study. If nothing in that particular context is arranged, the factor is not present in that specific case. The full list of questions can be found in Appendix D.

The interviews should provide insights on if and how the factors under study occur in a practical setting. Besides, participants may share their views on governance in such arrangements. In the end, this provides an answer to research question 3.

3.1.3 Requirements

Determining which requirements are present in multi-cloud management and how they are dependent on the context requires a slightly different approach than presented in the previous two sections. Requirements have some overlap with mechanisms presented before. For the most part, they are deducted from the interview results on challenges and factors. This means that the analysis of the interviews should show what makes the arrangement work in each case. This includes the question of what is required for the organization to overcome certain challenges and manage certain factors. Examples of requirements are loose coupling, a clear division of roles, or certain agreements based on the type of multisourcing arrangement. Requirements and factors can also overlap. For instance, it can be required that data is properly managed, while data management as a factor also influences the quality of multi-cloud management.

The analysis of the interviews should make it possible to identify requirements for effective multi-cloud management and answer research question 4. Along with the answers to the other questions, this can be used to formulate the framework in Chapter 4.

3.1.4 Overview

In short, the interviews should help in identifying challenges, factors, and requirements for effective multi-cloud management in a practical setting. This includes questions on the problems encountered when managing multi-cloud, what mechanisms are in place to mitigate them, and what the strengths and weaknesses of these mechanisms are. Besides, different types of governance and management are discussed, along with how they occur in that particular context.

For each case, it should be assessed to what degree the form of multi-cloud management is effective in the context of this thesis. This provides insights on which factors and mechanisms are present in effective governance and management arrangements. These findings can then be used for the development of the framework in Chapter 4.

Note that this assessment is ambiguous to some extent, as there are no specific KPIs defined in this thesis. Effective management correlates with asset utilization, and describes to what extent the desired functionality of a system is reached. This is in line with the definitions of effective management in the previous chapters.

Answers to the questions described in this paragraph can be used in combination with the literature review to answer research questions 2 to 4. Besides, the framework in Chapter 4 is based on these outcomes. Both the outcomes to the questions and the framework are then evaluated in Chapter 5.

3.2 Cases

This section addresses the different case studies separately. Each interview is one case. For each interview, the key takeaways from the summary and analysis are listed at the start. Then, a short summary is given, which explains the nature of the case in more detail. This entails what the multi-cloud system looks like, how many applications are approximately used, and how this is orchestrated. This is followed by analyzing the interview by means of the conceptual framework in Figure 2.3. This analysis also shows which factors are present in this arrangement and how they appear. This is accompanied by a table that lists the challenges, factors, requirements, and mechanisms for each case. High-level factors like relational or contractual governance are expected to always play a role. Therefore, these are not included in these tables, but can be addressed in the text of the analysis.

The key takeaways should be interpreted as a high-level summary of the notable points of each particular case. While cases may have overlap on certain points, these points can be more important for one case than for another. For instance, both Case 3.2.1 and 3.2.2 show the importance of data management, but in Case 3.2.1, this importance is further emphasized by the participant. Therefore, data management as a crucial factor is a key takeaway of Case 3.2.1, but not of Case 3.2.2, as other findings are more relevant in that particular case. Still, data management as an important factor is shown in the results of both cases (see Tables 3.1 and 3.2).

3.2.1 Case 1

Key takeaways

- Data management is a crucial factor for effective multi-cloud management
- An integration layer connects all applications with minimal complexity and is similar to a traditional ESB
- Collaboration is key and comes from both contracts and relationships
- There is a shift from traditional IT management to a DevOps way of working

Summary

This interview is conducted at a large, international, professional services firm. The interviewee is CIO within the organization. At the time of the interview, most of their IT landscape runs on three different cloud platforms. In the near future, this will be expanded even further. There is still a part of the IT system on premise. Because of the size of the company, they use over a hundred different applications, which are all connected to each other.

These applications and platforms interact with each other by means of a so-called Network Integration Layer. According to the interviewee, this is similar to a traditional ESB. This is needed for interconnectivity between the system. That means that the applications are able to communicate with each other. Besides, they use an additional data platform, which runs on one of the cloud platforms. All relevant data in the system is gathered and managed using this platform. The Network Integration Layer is part of this, and communicates with each platform and application by means of APIs. This prevents direct connections between all systems, minimizing complexity. Besides, this increases flexibility in the system. In data management, the quality of data must be high, as it is used by multiple systems. The interviewee states that data management is the most important factor for successful integration. The integration layer consists of building blocks by different providers.

Contracts are quite detailed in this arrangement. For this organization, it is crucial that the systems are up and running 24 hours a day, every day of the week. Therefore, this is high on the list of points on SLAs. Because of the size of the organization, they were able to negotiate non-standard contracts in which the cloud providers hold less dominance. This is also due to the high degree of capabilities that the organization has. There are no (forced) agreements between the providers. Everything is connected by the data platform and Network Integration Layer, making such agreements redundant. Furthermore, the contracts have a duration of around eight years, as this is the average lifecycle of IT systems.

Responsibilities for problems following from these contracts depend on where these problems occur. The organization is accountable for its own data, but every party has a certain responsibility. For instance, if something goes wrong in the technical infrastructure, responsibility lies with the infrastructure provider. In the end, solving such issues requires collaboration between all parties. For this collaboration, there is a main point of contact for each party. Besides, there are protocols in place for every type of incident.

In terms of governance, the respondent recognizes business governance as the overarching type. According to the interviewee, everything else is an element of this. Still, there is room for separation of certain parts, like governance on the Enterprise Architecture level. The business governance describes high-level objectives. Relationships with other parties in the system are quite mature. This is due to the experience and size of the organization, along with the duration of the contracts. These mature relationships have trust as a byproduct.

The impact of new releases by cloud service providers is always assessed before deploying them. This concerns the impact on all parts of the IT landscape. So, impact on other SaaS solutions, but also on the underlying platforms. This is tested and modified until the desired functionality is achieved. This often requires customization, which is also caused by legacy systems in the IT environment. This continuous testing comes from a DevOps perspective. This is overtaking elements of traditional IT management. Nonetheless, traditional IT management still plays a role. While technical management is mostly outsourced, most of the other elements are managed by the organization themselves. However, for applications that are completely build on a cloud platform, traditional IT management is not necessary anymore. Such applications are fully dependent on the DevOps cycle.

Analysis

The multi-cloud environment in this case is an elaborated one. There is a large number of applications and platforms in this IT landscape, along with certain on premise facilities. As there are multiple public clouds and on premise facilities, this system can be classified as both a hybrid and multi-cloud system. Linking back to Section 2.3.1 and Figure 2.1, the majority of this system is library-based, because the different applications are linked in terms of data. This is done by creating connections between the API of each application and the API of the integration layer. Although the integration layer, along with the data platform, consists of building blocks by different cloud service providers, it only runs on a single cloud platform. Therefore, it is not a service-based multi-cloud solution.

The organization manages their relationships, contracts, and procurement themselves. Besides, they do not force agreements between different cloud service or platform providers. The organization is both responsible and accountable for the combination of the different clouds. Therefore, this is similar to the direct multi-sourcing model as presented in Figure 2.2 (Wiener & Saunders, 2014). Still, the need for collaboration is high, as is displayed by how problems are mitigated. While contracts form the basis of this collaboration, most of it comes from clear communication and division of responsibilities. Besides, there is a Chief Data Officer who is in charge of all aspects around data, as well as the data platform. This role is similar to the role of Chief Cloud Officer suggested by Prasad et al. (2014). The organization also has a lot of in-house capabilities. This translates to organizational maturity on the IT domain.

Traditional forms of IT management are still present in this multi-cloud environment, but there is a shift towards a DevOps way of working in newer elements of the system. However, all these elements serve the business governance and the BLOs. On the technical level, there is a lot of customization. This led to some difficulties for the integration of certain parts. Standardized applications may have been easier to connect, but would have had less of the desired functionality. Furthermore, security and privacy concerns always have a role in such a system. Again, the organization collaborates with service and platform providers to manage this. For this joint technical

effort, relational governance is an essential factor.

This case shows the importance of the different types of governance presented in Chapter 2. Furthermore, it emphasizes the role that data plays in the world of multi-cloud. An important mechanism that is presented to simplify integration and coordinate applications is the use of an integration layer, similar to a traditional ESB. Other mechanisms are a Chief Data Officer and a clear division of roles and responsibilities to aid in collaboration between all parties. This entails both contracts and relationships. However, the organization under study is well-established, and has mature relationships with cloud service and platform providers. Such collaboration may therefore not be feasible for smaller organizations. All identified challenges, factors, requirements, and mechanisms are shown in Table 3.1 below.

Challenges	**Factors**	**Requirements**	**Mechanisms**
Interconnectivity		Division of roles	
Security	Collaboration		SLAs
Data management			Integration layer
	IT maturity		Cloud office
	Relationship maturity		BLOs

Table 3.1: Results of Case 1

3.2.2 Case 2

Key takeaways

- Relational governance is an important factor in the multi-cloud environment
- An integration platform minimizes complexity
- Collaboration is essential in mitigating most challenges
- A mediator can compensate for knowledge gaps in the governance structure

Summary

This interview is conducted at an employment agency. The interviewee is IT director within the organization. They use two main SaaS solutions, with each one running on a different public cloud. Besides, they use some other smaller cloud applications. Furthermore, they have IaaS for elements like data storage. This is a best-of-breed set-up, which is designed to achieve the highest functionality. This is explicitly stated by the participant, who says that there is no single system that provides everything they need.

The most challenging part of their multi-cloud environment is connecting all applications to each other. This comes back to data management. It is important that when data is changed within an application, that this change also occurs in the other applications. For example, if one of their candidates changes their address. For this

purpose, the organization wants to introduce a master database to which all applications are connected. However, at the time of the interview, this has not yet been implemented. The applications and services are connected by means of an integration platform. Within this integration platform, data mapping occurs to make data compatible between all applications. While two applications would be relatively easy to connect, such a platform is essential when working with more than that. Due to this platform, there are no direct connections or agreements between other stakeholders. The connections between the platform and the applications have been build by means of their APIs, and has been done by a third party. This third party can be seen as an integrator.

The organization works together with an IT service provider, who acts as a mediator in certain situations. For instance, when a problem occurs in the system, the IT provider investigates who is responsible and what effort is required to fix it. However, this only occurs with problems that the organization themselves can not locate and solve. For this, they have a support team in place. Over the years, this team has acquired much experience in dealing with issues in their system, which makes them less dependent on their cloud or IT service providers. While the mediator has helped with arranging SLAs and monitoring them, the organization has procured the cloud services individually. The duration of contracts is initially two to three years, with a notice period of around three months.

There is a lot of relationship management from the organization towards the cloud service providers. There are many evaluation moments and check-ins, which result in mature relationships and much trust between the stakeholders. This is important, according to the interviewee, because it provides the connections that are needed to manage the system correctly.

While most of the technical management is outsourced to either the IT service provider or the cloud service providers, small technical management elements are performed by the organization themselves. Identity and access management is done in collaboration with the IT service provider. The IT service provider is responsible for the single sign-on system, while the organization provides role-based access. That constitutes a part of the security side of management. In terms of privacy, it comes back to data management. This means that data is only in the application where it should be. A master database should make this easier.

Change is managed in collaboration with the relevant stakeholders. When updates of certain applications are released, the organization is usually in the early majority of adopters. Legal changes are discussed with relevant stakeholders, and is followed by applying the same protocols for new releases.

Analysis

There are two main public clouds on which this system runs. Therefore, it can be classified as multi-cloud. Furthermore, the multi-cloud system is library-based, as each application runs on a single cloud. The applications are connected by means of an

integration platform, in which data mapping occurs. This increases the functionality of the system, and eliminates the need for arrangements between all cloud service providers.

For a large part, the arrangement is mediated. However, the organization also handles certain matters on their own. The role of the IT service provider can be seen as a guardian vendor, as discussed in Section 2.4.1. In this case, the mediator assists the organization in their governance structure by executing work that is beyond the scope of the organization's capabilities. Besides, they are tasked with a part of contractual governance by setting up and monitoring SLAs with the cloud service providers. This is similar to the role of trust service provider proposed by Fan and Perros (2014), which is discussed in Section 2.3.4. The roles of mediator and integrator are split in this arrangement, and are allocated to two different parties. The support team of the organization initially handles most problems. They have acquired much knowledge and experience over the years, making the organization more mature.

Relational governance is an important factor in this case. Relationship management increases trust and makes it easier to find the right people at cloud service providers when there is an issue. Besides, this is also beneficial from the perspective of the cloud service provider. If the organization is content with the services, they are more likely to stay. Service level governance is mostly executed by the use of certain protocols, which, for example, dictate how employees can address issues and how these issues are then handled. For the technical level, many aspects are outsourced. Some minor elements are executed by the organization, but the largest part of IT management on all levels is done either by or in collaboration with the service providers in the ecosystem.

Data management plays a large role too. This is why the organization eventually wants to implement a master database. It also requires attention in the integration platform, where data mapping occurs. Overall, high functionality in the system is achieved by fine-tuning relationships with all stakeholders and minimizing complexity by means of an integration platform. All identified challenges, factors, requirements, and mechanisms are shown in Table 3.2 below.

<table>
<tr><th>Challenges</th><th>Factors</th><th>Requirements</th><th>Mechanisms</th></tr>
<tr><td>Interconnectivity</td><td>Relationship maturity</td><td>Clear communication</td><td>Integration platform</td></tr>
<tr><td colspan="3">Data management</td><td>Mediator</td></tr>
<tr><td>Privacy</td><td colspan="2">Relationship management</td><td>SLAs</td></tr>
<tr><td></td><td>Collaboration</td><td>Division of roles</td><td>Support team</td></tr>
<tr><td></td><td>IT maturity</td><td></td><td></td></tr>
</table>

Table 3.2: Results of Case 2

3.2.3 Case 3

Key takeaways

- Unclear inter-organizational governance leads to difficulties
- XLA is an alternative to SLA, in which user experience comes first
- Avoiding direct connections by means of an integration platform minimizes complexity
- Existing frameworks provide a solid foundation for many management elements

Summary

This interview is conducted at an educational institution. The interviewee is IT manager within the organization. They work with a variety of cloud applications from different vendors, which run on different clouds. These applications vary in purpose. Some are for students, while others are for employees, HR purposes, or workflows. The organization has chosen a best-of-breed solution for the highest functionality. This solution has been chosen by best-value procurement, after which one party was selected to orchestrate all applications. This party can be seen as the mediator. Besides, the organization has one application running on premise.

The mediator also plays the role of the integrator in this situation. This party suggested that the organization also procured another cloud application, which would work seamlessly with the already implemented HR technology. These cloud service providers had a partnership, and had standardized the connections between their services. However, standardization was not as high as expected, which made it difficult to connect the applications as there was a lack of interoperability. This resulted in distrust between the organization and the mediator. For the connections between the other applications, an integration platform is used. This platform is also a cloud solution, and functions like a traditional ESB.

The organization uses XLAs instead of SLAs. This stands for Experience Level Agreements, and means that performance of the system is measured by how users rate their experience of the system. Besides, there are no hard requirements in the contracts. This is measured by evaluating the system frequently, and determining if the performance of the system lives up to the expectations. This is a qualitative approach to monitoring these XLAs. An alleged advantage of this approach is that it stimulates collaboration. Most contact moments are with the mediating party. Meetings with cloud service providers are less frequent, but

IT management inside the organization is for a large part executed by means of frameworks and standards. A large part of responsibilities is allocated using the RACI matrix. This was done after the incident described before. The use of this framework resulted in a clear division of roles, responsibility, and accountability. This was essential for rebuilding the trust that was lost. However, the organization is still cautious and emphasizes the need for an exit strategy, in case things go wrong.

In terms of security, the organization also uses existing frameworks. Identity and access management is important to them, and is done by single sign-on and multi-factor authentication. In the future, the organization wants to implement role-based access.

Analysis

The organization uses a range of applications that run on different public clouds. Besides, they have on premise facilities. Therefore, this can be classified as a hybrid and multi-cloud system. Besides, this system is library-based because each applications runs on a single cloud. The applications are connected through an integration platform. However, some applications also have direct connections. This is where integration issues occurred, which was caused by multiple factors. On the technical level, there was less standardization than expected, which made it hard to connect the services to each other. Furthermore, there were overlapping roles and responsibilities. The mediating party sold another service to the organization, but they were also the integrator of the service. Thus, they provided themselves with more work. This can be seen as a conflict of interests. When the implementation was flawed, the stakeholders held each other accountable. The mediating party accused the organization of lacking clear objectives, which can be seen as BLOs.

Inter-organizational governance has had much influence in this case. Unclear roles led to issues, which in turn led to distrust in the environment. Afterwards, relational governance and management were approached in a more structured and clear way. Still, it takes time to rebuild the relationship. The organization also has an elaborate exit strategy, which could be another sign of a lack of trust in the environment. This is because they are already considering what will happen when the arrangement comes to a stop, either by their choice or that of another stakeholder. This is notable, because the arrangement is less than a year old, and thus quite novel.

Another interesting point is the contractual governance, where the organization uses XLAs instead of SLAs. This may be a mechanism that results in better collaboration than regular agreements. However, no conclusions on that hypothesis can be drawn from this case. XLAs are also a mechanism for service level governance, because users within the organization are more involved in service management by being able to share their experience.

The remainder of intra-organizational governance comes mainly from existing IT frameworks, similar to the conceptual framework in Figure 2.3. These are used for risk management, data management, and handling new releases. Overall, the most influential factor in this case is relational governance. After some difficulties, the RACI matrix was used to structure some elements of this. All identified challenges, factors, requirements, and mechanisms are shown in Table 3.3.

Challenges	Factors	Requirements	Mechanisms
Interoperability	Standardization	Business Level Objectives (BLOs)	
Security	Division of roles		IT frameworks
User experience	Risk management	Clear communication	XLAs
Collaboration			Integration platform
	Data management		
	Trust		

Table 3.3: Results of Case 3

3.2.4 Case 4

Key takeaways

- BLOs are required to effectively govern the multi-cloud environment
- Collaboration is an important factor that includes involvement of all stakeholders
- A cloud office helps with managing roles and responsibilities
- Data management is required for reliability within the system

Summary

This interview is conducted at a financial services provider. The participant is part of the project management team that guided the implementation and use of multi-cloud within the organization. The organization uses a variety of SaaS solutions, which run on two major platforms (PaaS). Furthermore, the organization uses some IaaS components. The reason behind this set-up is that it increases reliability and lowers the amount of risk within the system.

Each application runs on both platforms. However, for each of the applications, one of those platforms is the 'leading' platform. The other platform functions as a back-up, in case of failure. There is a direct connection between the platforms to transfer data and other information needed to run the applications. This approach should increase reliability of the system, as there is always one platform available to run the application on. At the time of making this decision, which was around 2016, the organization thought that it was a risk to outsource this part of the system to only one provider.

In the first phase of working with a multi-cloud system, the organization experienced difficulties as not everyone within the organization supported the strategy. Some objectives were not clear, and the IT department could not initially convince the business side of the organization about the advantages of such a system. This changed when a business case was set up. This showed the financial and organizational benefits, and clearly explained the goals of the multi-cloud strategy. Furthermore, this included an explicit division of roles and responsibilities, including a

program owner, and a tech, data, and security lead. Together, these people formed a Cloud Competence Center. This supported decision-making within the organization.

The organization uses an architecture model to manage the system. This includes components like service management, cloud solutions management, and security. This is decomposed into smaller elements and requirements. The model also covers aspects like relationship management and identity and access management.

The organization makes use of SLAs with all cloud service providers. These were negotiated with each provider, and consist of KPIs like inventory levels, time to market, and IT costs. Service components like support coverage, service availability, and restoration time are also incorporated into these agreements. The cloud service providers were willing to incorporate the wishes from the organization into all contracts. Contracts with the providers have a duration of around five years. The organization believes that the two platform providers already have agreements in place, and does not meddle in those agreements.

The service providers have dedicated points of contact in case of failure in the system. The participant emphasizes the dedication and devotion that the service providers showed in order to achieve an optimal IT environment. Along with much involvement of all parties, this resulted in a high amount of trust between all stakeholders. This trust is maintained by planning frequent meetings and ensuring involvement of all stakeholders. The responsibility of maintaining the relationships lies with the Cloud Competence Center, which was addressed before.

Analysis

Two major PaaS solutions are used in order to support the whole system. These platforms can be classified as public clouds. Therefore, this system is a multi-cloud system. It is also a direct arrangement, as there is no mediating party involved.

The majority of the system is library-based. Nonetheless, most applications run on both platforms. This is a form of service-based multi-cloud, as is shown in Figure 2.1. However, data on the technical side of this case could not be acquired. Due to that, it is unclear how these solutions are connected. There are connections between all systems, but it is unknown if these connections are either direct or by means of an integration platform.

The organization recognizes the need for relational governance. In this particular case, that is both internal and external. Within the organization, the IT department must be in line with the rest of the business. This is achieved by formulating clear BLOs and the appointment of a cloud office. The external side of relational governance considers the relationships with the cloud service providers. This is managed by planning frequent meetings. Again, the cloud office holds this responsibility.

On the contractual level, SLAs are used to govern the performance of the multi-cloud system. These agreements have been composed in collaboration with all cloud

service providers, and consist of various KPIs. The contracts also cover how the organization can reach the providers in case of difficulties.

A business governance perspective on this case shows the importance of involvement of all stakeholders. Only when all internal stakeholders were involved and saw the benefits of this strategy, the multi-cloud system could be effectively managed. Again, the cloud office played a big role in this. A clear division of roles and responsibilities supported decision-making within the environment, and made it easier to govern the whole system. People within the organization knew who they needed to approach for certain topics.

Although the technical part is unclear, the participant recognizes the challenge of interconnectivity in the system. This includes security concerns and data management. These aspects are covered by the architecture model that the organization has set up. This is also a part of risk management in this case.

Note that in this case, it is hard to assess the technical side due to a lack of data. This also goes for the use of IT frameworks. However, enough data is available to discuss the governance factors that are present in this case.

Challenges	**Factors**	**Requirements**	**Mechanisms**
Interconnectivity		Business Level Objectives (BLOs)	
Collaboration		Clear communication	Cloud office
Security	Data management		SLAs
	Trust		Division of roles
	Risk management		
	Relationship management		

Table 3.4: Results of Case 4

3.3 Cross-case analysis

All cases are now clear and summarized, and their key points highlighted. In this section, the cases are compared to each other. This is called a cross-case analysis. This helps with identifying patterns, and emphasizes important differences between cases. First, the approach to this analysis is explained. This is followed by patterns that are observed when comparing the cases. The remaining sections elaborate on those patterns. In the end, this analysis can be used as a foundation for the management and governance framework that this thesis is aimed to produce.

3.3.1 Approach

A cross-case analysis is an essential part in a multiple-case study (Yin, 1994). In this thesis, the guidelines proposed by Miles and Huberman (1994) are used for data representation and analysis. They propose three steps: data reduction, data display,

and drawing conclusions. This part of the section explains these steps, and how they are applied in this chapter.

Data reduction is done by categorization. For this purpose, the conceptual framework that came from the literature review is used. Answers given by participants are allocated to a form of governance or management. If needed, these categories can contain subcategories to further specify where a factor or requirement should be allocated.

The categories and the factors they contain are then visualized by means of a diagram. In this diagram, the cases are also included. This gives a simple overview of all factors, requirements, and mechanisms, and in which cases they occur. This makes it easier to observe certain patterns in the collected data.

The final step is drawing conclusions. This entails deciding which patterns are relevant, and which points from the comparison are notable. The data display from the previous step supports this. All of these steps are worked out in Section 3.3.2. The remainder of this section further elaborates on these findings, and discusses what they mean in the multi-cloud context.

3.3.2 Qualitative data analysis

This section focuses on data reduction and visualization. As stated before, categories are deducted from the conceptual framework in the literature review. All relevant challenges, factors, requirements, and mechanisms are then divided into those categories. These come from Tables 3.1, 3.2, 3.3 and 3.4, and are all labeled *factor* for the sake of simplicity. All these factors are displayed in Table 3.5, along with in which cases they occur. To keep things clear, some factors have been grouped together. This goes for Support Team from Case 2, which is now part of Cloud Office, and for Integration Layer from Case 1, which is now part of Integration Platform.

There is a number of factors that occur in every case. These are an integration platform, data management, security and privacy, collaboration, and a division of roles. Note that the presence of an integration platform in Case 4 is unknown. Furthermore, *n*-level agreements also occurs in every case. However, it is either SLA or XLA. The interviewee in Case 3 explicitly stated that they use XLAs instead of SLAs.

The factors interconnectivity and interoperability are closely related to each other. Where interconnectivity focuses on how well systems connect and communicate with each other, interoperability addresses how well systems operate with each other. In that sense, interconnectivity might be a part of interoperability. Both are elements of integration.

A number of other factors can be observed in at least two of the case studies. These factors are IT maturity, BLOs, a cloud office, relationship maturity, a mediator, relationship management, and clear communication. Some of these factors depend on the type of arrangement, like a mediator. The other factors might have another connection to the case. For instance, factors on relations, maturity, and a cloud office did

Categories		Factor	Case 1	2	3	4
Business governance	Technical level	Integration platform	X	X	X	?
		Interconnectivity	X	X		X
		Interoperability			X	
		Data management	X	X	X	X
		IT maturity	X	X		
		Security and privacy	X	X	X	X
		Risk management			X	X
		Standardization			X	
	Service level	BLOs	X		X	X
		User experience			X	
		IT frameworks			X	
Inter-organizational governance	Relational governance	Cloud office	X	X		X
		Relationship maturity	X	X		
		Mediator		X	X	
		Collaboration	X	X	X	X
		Trust			X	X
		Relationship management	X	X		X
		Clear communication		X	X	X
	Contractual governance	Division of roles	X	X	X	X
		SLAs	X	X		X
		XLAs			X	

Table 3.5: Data display of all factors in the multiple-case study

not occur in Case 3. In that case, there was distrust and there were implementation issues in the multi-cloud environment. In the case itself, it was concluded that this was due to a lack of division of roles. However, the aforementioned factors were absent too, which might have contributed to the situation. This means that these factors are also relevant in the multi-cloud context.

The following sections discuss the factors that occur in every case. First, the use of an integration platform is discussed. Then, data management is addressed in more detail. This is accompanied by security and privacy, and followed by a section on collaboration and the division of roles. This analysis is concluded with a section on SLAs and XLAs.

3.3.3 Integration platform (as-a-service)

An integration platform is seen as a good practice by all of the participants. This is usually best applicable in a library-based multi-cloud system. That means that there are multiple connected applications which are running at different cloud providers. However, each application is running at a single cloud provider. Still, this can result in a complex IT landscape, as the different applications need to exchange data in a

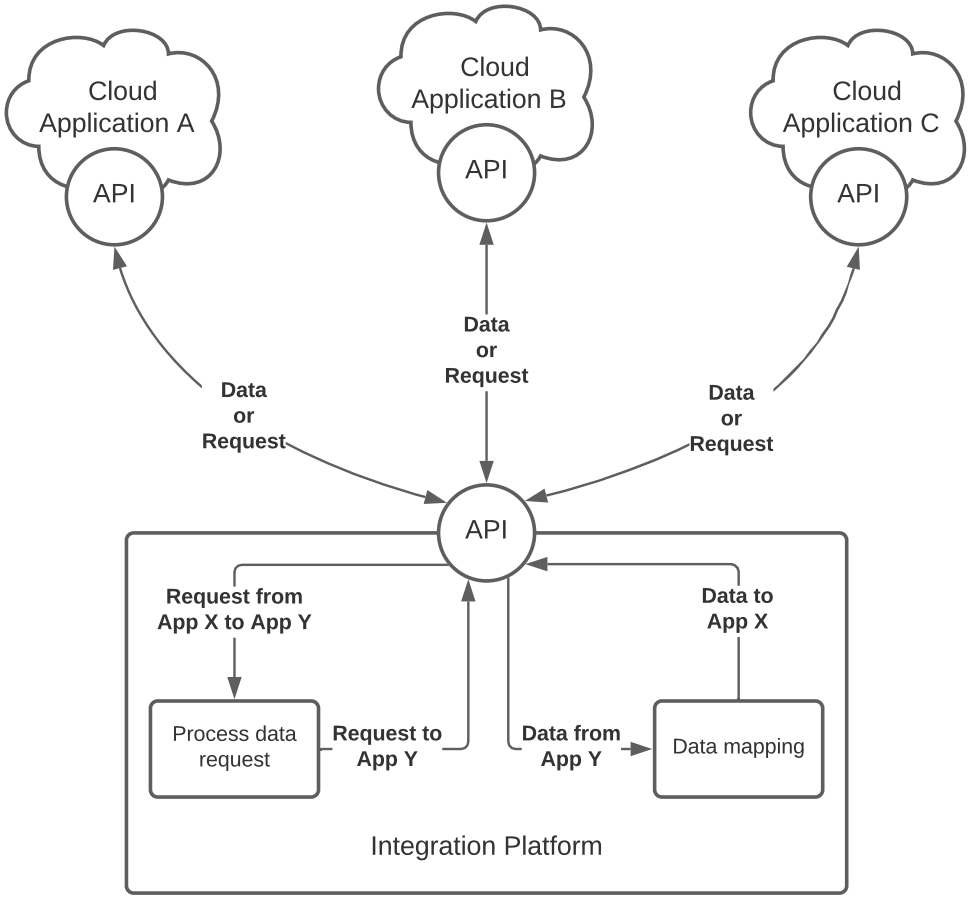

Figure 3.1: Dataflow in a library-based multi-cloud system with an integration platform

secure manner. An integration platform helps in secure data exchange, as it eliminates the need for agreements between the different cloud providers.

The dataflow in a system using an integration platform is displayed in Figure 3.1. In comparison with other models of the multi-cloud environment (for example, Figures A.2 and 4.2), the absence of direct connections between the systems can be observed. As stated before, this reduces the complexity in the system and eliminates the need to manage relations and connections between cloud providers. The participant in Case 2 stated:

"Our integration platform is like a power strip. We can easily plug in or pull out certain applications. It requires some effort to create that connection, but once it is in place, it is very easy to use."

Within the platform, data mapping occurs to make the data compatible with each application. The system is comparable to a traditional ESB, as a number of participants indicate. However, an ESB simply passes on messages, where an integration

platform can also manipulate data. A platform like this can also be procured as a cloud service. In that case, the platform is called an Integration Platform-as-a-Service (iPaaS). The possibility of an ESB as an integration method is also presented by Sun et al. (2010) and Kritikos et al. (2019), as discussed in Sections 2.2.2 and 2.3.4, respectively. In the aforementioned section, this was combined with the concept of a service broker. The use of iPaaS is briefly addressed in the system analysis in Appendix A.

One of the biggest benefits of an iPaaS is that it supports a loosely coupled architecture. This increases the interconnectivity and interoperability of the system, which were dubbed as challenges in the multi-cloud context in the multiple-case study. From a security and data privacy perspective, such a platform makes the system more transparent. This is related to data management. All of these aspects are discussed in the next section.

3.3.4 Secure data management

All respondents recognize the importance of data management in the digital world. This includes compliance to legal requirements, but also refers to technical security requirements. Detailed approaches to this are beyond the scope of this thesis, but it is still important to consider the role of data in managing multi-cloud systems. Some mechanisms addressed by the participants are specifically relevant in the multi-cloud context.

The interviewee in Case 2 indicated that they want to implement a master database. This can be another cloud service, which can be combined with an iPaaS from the previous section. The master database then functions more as a generic data layer. The integration platform then translates it to the language of the application in need of the data. This translating of data constitutes the data mapping that has been discussed in this chapter.

Security and privacy of both the system and data are essential elements of a multi-cloud system. Therefore, they must be addressed, despite the fact that one could write a whole thesis on each of those points. In all cases, one of these elements is seen as a challenge. There is a range of technologies which can support security and privacy, like encryption, multi-factor authentication, and many others. A recurring theme throughout this thesis is identity and access management, which goes more into roles and authority of users of the system. All of this is also important from a risk management perspective.

For data privacy, the interviewee in Case 2 states that they only exchange data between applications that is needed. A lot of sensitive information is only stored and used in one system. When using a master database, this sensitive information will have to be exchanged between the database and the relevant application. In that case, it is crucial that the data is well-protected, either by encryption or other privacy-enhancing technologies.

Methods for data compliance and information security also include the use of frameworks and standards, like the ISO27001 standard. Such standards are still relevant in the multi-cloud context, as is demonstrated in Case 3. In that case, the organization has been able to apply these standards in their system. Overall, an organization should consider how they implement and manage these issues, preferably from the start. This is called Privacy- and Security-by-Design. This method makes it easier to mitigate these challenges, as they are used as principles when composing the system.

3.3.5 Collaboration and dividing roles

All participants recognized the importance of collaboration. A clear division of roles is a crucial factor in this. Case 3 showed that when this is lacking, it is harder to resolve issues. This can result in distrust, which can hurt performance (Sabherwal, 1999). It is also in line with the literature review, which states that mutual trust and interdependence are essential factors in IT outsourcing arrangements (Ali et al., 2017; Rhodes et al., 2016).

These interdependencies are a big part of Coordination Theory, as discussed in Section 2.4.3. Coordination is all about managing them, which is an important element of multi-cloud management. In turn, this supports collaboration. It is interesting to look at the mechanisms that are presented in the cases to achieve effective collaboration.

In Cases 1 and 2, relationship management and maturity are a relevant factor. In Case 3, the use of existing frameworks supported the division of roles and responsibilities. This was already in place in the other cases. Relationship management and maturity are interrelated, as one leads to the other. Still, both are important factors. Nonetheless, it starts with dividing roles. When these are clear, all stakeholders in the arrangement can build on this. Another factor in this is clear communication. This means being transparent, and keeping each other up-to-date. This can be approached by planning frequent meetings and evaluations.

Case 4 showed that a vital part of collaboration is the involvement of all stakeholders. This is also an element of relationship management, which is crucial for effective collaboration. Furthermore, the involvement of stakeholders provides the possibility for everyone to express their views.

It can be an overwhelming task to get the governance structure right. In the multi-cloud context, a mediator can be appointed to support this. Other supporting roles can be a consultant or an integrator, as can be seen in the system analysis (Appendix A). However, the mediating party is most relevant in this case, and can also be seen as the guardian vendor (Wiener & Saunders, 2014; Bapna et al., 2010).

Due to experience, the role of the mediator can eventually become smaller, as is displayed in Case 2. This means that the organization is gaining more knowledge on the governance structure and relationship management. Besides, it is a sign that relation-

ships are getting more mature. Still, the emphasis should be on a solid foundation. Without it, relationships, trust, and knowledge have nothing to grow on.

3.3.6 From SLAs to XLAs

Where SLAs are most commonly used, as is displayed in Cases 1 and 2, an alternative is the use of XLAs. A quick literature search on `"experience level agreement"` shows that XLAs, also called ELAs, are much more user-centric than network-centric SLAs (Varela et al., 2015). This also means that the Quality of Experience (QoE) should be high, instead of the Quality of Service (QoS) (Robitza et al., 2017). One of the benefits of XLAs is that the focus is on the end-user. Still, QoE can als be implemented in SLAs, retaining the benefits of those.

3.4 Validation of the multiple-case study

This section discusses the validity of the cases and the associated findings in this chapter. As described in Section 1.5.2, this is executed in accordance with the work by Yin (1994). In this thesis, both internal and external validation are used to substantiate the findings.

3.4.1 Internal validation

Internal validation describes the credibility of information in each case. Although the case studies in this chapter are relatively small, at least two different information sources are used to investigate each case. One of these information sources is a formal, recorded interview with a person that is involved in the management of the organization's multi-cloud system. Other information sources are documents describing the multi-cloud system or the architecture around it, and informal interviews with colleagues that work or have worked with the organization under study. Table 3.6 shows the number and type of information sources that are used for each case study.

	Information source		
Case	Formal interview	Informal interviews	Documents
1	1	2	4
2	1	1	1
3	1	2	0
4	1	1	2

Table 3.6: Number of information sources for each case study

By using a variety of information sources, the internal validity is increased. Participants in the interviews can be biased. For instance, they are not likely to admit that their organization has made a mistake, and thus blame another stakeholder. Informal

interviews with independent people who know the case makes it possible to avoid this bias, and increase the credibility of the information. The same goes for certain documents. Using this approach, the internal validity of the findings of this thesis is increased.

3.4.2 External validation

External validation describes to what degree the findings from the multiple-case study are generalizable. That means, if the findings also apply in a general context. As described in Section 1.5.2, this is approached in two ways in this thesis. One of those ways is replication, which is described in this section. The other is by asking a subject matter expert. This part of the validation is presented in Section 5.2.1.

In order to generalize findings from a case study, "a theory must be tested through replications of the findings in a second or even a third neighborhood, where the theory has specified that the same results should occur" (Yin, 1994, p. 36). The multiple-case study covers four different cases. In the previous section, patterns and similarities between these cases are discussed. A number of findings is present in all cases, which is also hypothesized in Chapter 2. The fourfold replication increases the external validity of these findings, which makes them generalizable. Therefore, they can be used to develop the governance and management framework in the next chapter. Besides, the generalizability is double-checked in Chapter 5.

In summary, the internal validity of the cases is substantiated by using different information sources for each case. The external validity of these findings is supported by replication. The latter form of validity is elaborated on by explicitly asking a subject matter expert about the generalizability of these findings. This is discussed in Section 5.2.1.

3.5 Conclusions from the interviews

This section describes the conclusions from this chapter, and how they relate to the findings of the literature review in Chapter 2. Together, they should provide answers to research questions 2 to 4. From there, the foundation for the governance and management framework can be composed. This framework answers the main research question. This section is structured as follows. First, the findings from this chapter as compared to the literature review are addressed. This also answers the research questions. Then, the implications from these findings for the final framework are discussed.

3.5.1 Findings

For each case, all identified challenges, factors, requirements, and mechanisms are listed. This section investigates how this relates to the findings of Chapter 2. The overarching challenge that was identified in the literature review is integration. This

can be divided into smaller elements like interoperability, security, and privacy. For a large part, the results from the multiple-case study are in line with this. Identified challenges are interconnectivity, interoperability, security, privacy, data management, user experience, and collaboration. Some of these challenges are also an influential factor in the multi-cloud context.

There are many other factors derived from the interviews. An extensive list of all factors deducted from the literature review can be found in Table C.1 in Appendix C. It is interesting to look at the more specified factors than the overarching governance types of factors. It is clear that these types play a role, but the specific factors provide a better image of how this occurs. Factors that occur both in the interview and in the literature review are the following:

- Risk (management)
- Trust and relationship management
- Data management
- Security and privacy
- Interoperability
- Organizational maturity (IT and relationship maturity)

There exists a number of requirements and mechanisms to implement these factors the right way. From a relational and contractual governance perspective, these include a clear division of roles, either SLAs or XLAs, a cloud office, and clear communication. Another mechanism, but not necessarily a requirement, is the use of a mediating party. This depends on how mature the organization is. From a more technical perspective, mechanisms include proper identity and access management, an integration platform, and the use of existing IT frameworks. These can also support the requirement of clear data management. Finally, from a service level perspective, it is required to formulate BLOs. These support the overall mission of the organization, and can be used as principles for decision-making in the multi-cloud environment.

These findings provide answers to research questions 2 to 4. Challenges (research question 2) that occur in the literature review and are confirmed by the interviews are interoperability, security, and privacy. An additional challenge, but also an influential factor, is collaboration. The other challenges identified in the interviews are seen as factors to overcome the stated challenges. Factors (research question 3) that play a role in the listed challenges, and in the multi-cloud environment overall, can be found in the list above. Requirements (research question 3) that follow from these challenges and factors are a clear division of roles, clear, feasible contracts and agreements, clear communication, and formulated objectives.

3.5.2 Towards a governance and management framework

Requirements for effective multi-cloud management and governance are now clear. However, how this knowledge applies in a practical setting is not. This is where the framework comes in. A variety of mechanisms has already been presented in this thesis. Such mechanisms should fulfill the requirements, address all relevant factors, and in the end, mitigate the challenges.

The framework should then formulate how to deploy these mechanisms, dependent on the organization, and where to start. This way, a proper governance and management framework can be set up. This includes how to manage and coordinate all stakeholders, encourage collaboration, and achieve the optimal functionality of the multi-cloud system.

In the following chapter, this is worked out. This builds further upon the answers to the research questions provided in Section 3.5.1. Furthermore, it provides a workflow to achieve effective management in a multi-cloud environment.

Chapter 4

Coordination framework

This chapter describes the coordination framework for management and governance of multi-cloud systems. It is based upon all findings of this research up until this point. The framework should provide guidance in composing the governance structure for the management of multi-cloud. It is composed by looking at the requirements, and identifying the proper mechanisms to achieve those. As every situation is different, there are a lot of different options or mechanisms that work in only a particular case. All these options and how they occur are discussed after the initial framework is presented. The resulting framework is shown in Figure 4.1.

The chapter is structured as follows. First, the elements of the framework are discussed step-by-step in a general overview of the framework. This includes the requirements, considerations, and mechanisms to do so. Besides, the effects of these measures are discussed. The section is concluded with an overview and why this is a coordination framework.

The second part of this chapter explains the application of the framework. This considers who should use it, and how it should be used. This is demonstrated by means of a use case.

Section 4.3 describes how the findings from Chapters 2 and 3 have been translated into this framework. This comes third, as the main focus of this chapter is the framework itself, and not how it came about. However, it substantiates the reasoning behind the framework, and must therefore be included.

The chapter is concluded with a discussion on certain aspects and considerations. This also addresses why certain mechanisms are not included the framework, like OLAs. Furthermore, considerations about consultancy agencies and mediators are briefly discussed.

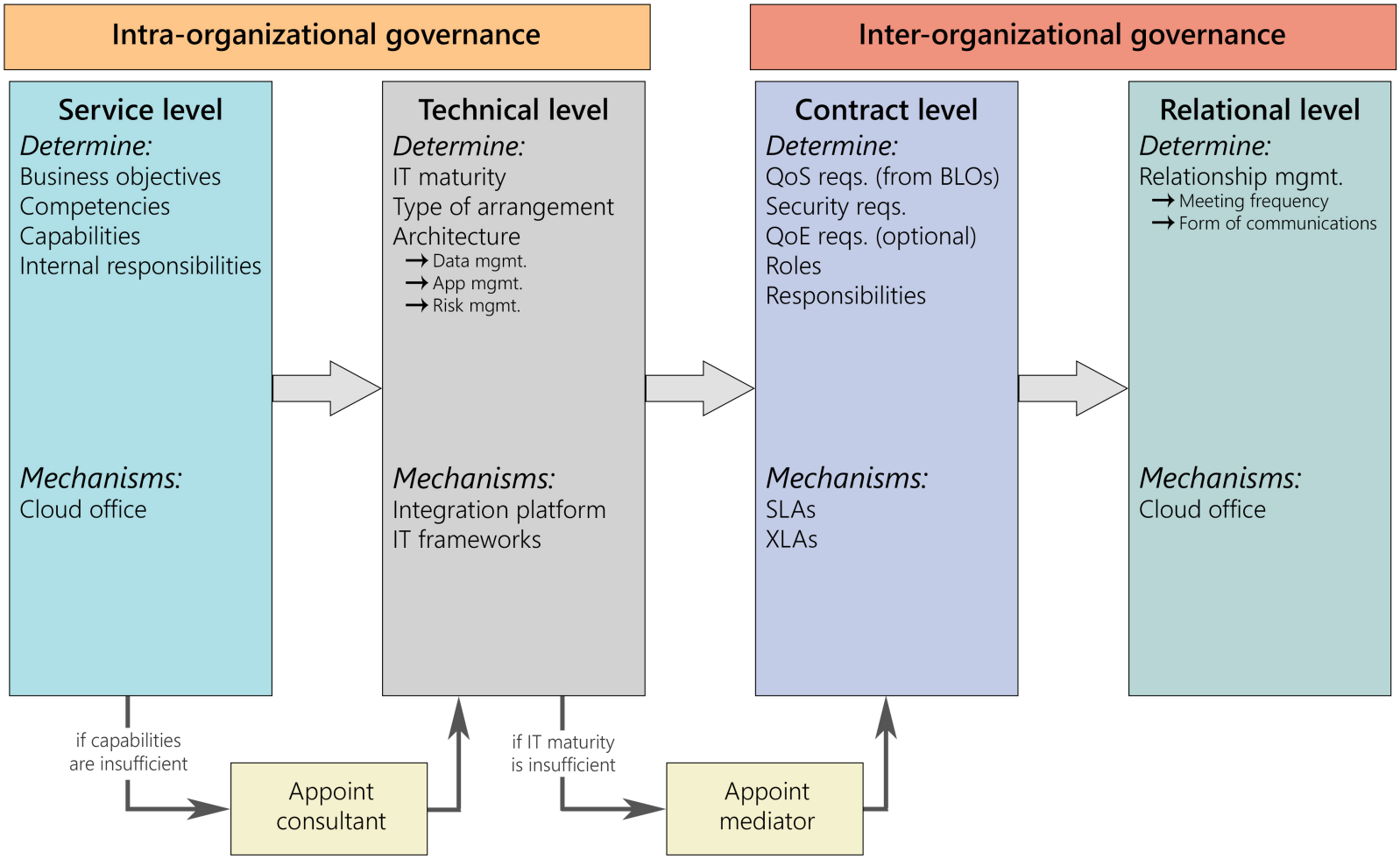

Figure 4.1: Framework for effective governance and management of multi-cloud systems

4.1 Elements of the framework

This section describes every element of the framework in detail. This goes from intra-organizational service level governance to inter-organizational relational level governance. Note that for clarity, business governance has been renamed intra-organizational governance. This name gives a better expectation of what to expect from that part of governance. Business governance may then be seen as overarching, but that discussion is not relevant to the framework itself.

Each section describes what that level aims to accomplish and how to approach this. For some sections, this includes examples and identified good practices. Besides, the organizational choices that need to be made are addressed.

The final section gives an overview of all discussed elements. Besides, it discusses why this framework is a coordination framework, and how this is portrayed by the elements. This is also a small bridge to Section 4.3, which further describes how the framework came about and what the thought process behind it is.

4.1.1 Service level

The first step in creating a governance structure for managing multi-cloud within an organization is to assess what the organization wants to accomplish. This starts with business level objectives. This entails questions like what the organization wants to achieve and what it stands for. Then, the organization can assess how a multi-cloud strategy fits into this picture. This provides a solid foundation, from where the goals can be further specified. This can already include some technical details, like the cloud services that an organization wants to procure to reach its goals. Further specification results in clarity on what the organization wants from their cloud providers, which supports clear communication in later stages of the process. Note that service level governance can also occur in inter-organizational governance. In this framework, that part is covered by inter-organizational contract level governance, which is described in Section 4.1.3. Service level in this section only covers the intra-organizational part.

When the goals and objectives are clear, the organization should assess what knowledge and capacities they already have. They should ask themselves which relevant competencies and capabilities they have. This correlates with IT maturity, which will be further specified in the following section. For now, the organization should decide if they have the capacities to assess their own maturity. If not, they can appoint a consultancy agency to assist them with that. Consultants can be hired in any part of the process, if the organization does not have the in-house knowledge to deal with certain issues. However, the organization should then determine if this is a cost-effective strategy. In most cases, hiring specialists to assist in these matters avoids mistakes in a later part of the process. The costs associated with those mistakes can be difficult to quantify, but should be considered when deciding to appoint consultants.

Another important point to determine in this stage is the internal division of re-

sponsibilities. The organization must consider which people within it are responsible, and who is ultimately accountable. A recommended mechanism is the use of a cloud office. This office can be composed of employees that are involved in managing the multi-cloud strategy. Tasks of the cloud office include monitoring and evaluating the system, making sure the strategy is being followed, and eventually also manage relationships with vendors. Besides, they are a point of contact for employees who run into difficulties. The cloud office should preferably include someone from senior management or in the role of CIO, and someone with technical knowledge on cloud computing. Within the cloud office, roles and responsibilities should also be properly divided. This is also important for decision-making during the process. Furthermore, the cloud office can have regular updates and check-ins to make sure that everything is going as it should.

Overall, this provides a solid foundation on which the organization can further build the management of their multi-cloud system. With a clear mission and strategy, the organization can go forward in this. When roles and responsibilities are clear, people within the organization know what to expect from others, and what is expected from them. From here, the organization can go to the next step.

4.1.2 Technical level

The second step is the intra-organizational technical level governance. Now that the internal structure is clear from the previous step, the technical environment can be build around this. The first step is assessing the IT maturity. This entails how much knowledge is in the organization on all technical aspects. This also goes for knowledge on new developments within the cloud world. Some of these competencies have already been identified in the previous step. The important thing in this part of the process is that there are people within the organization, preferably also in the cloud office, who are able to define the current and future IT architecture of the organization. If not, a consultancy agency can be appointed to assist with this. Based on the IT maturity of the organization, the type of arrangement can be determined. If IT maturity is high, the organization can choose to go for a direct model, and connect all cloud applications and services themselves. Otherwise, it is recommended to appoint a mediator. In the course of time, the role of this mediating party can be reduced, as the organization acquires more knowledge and experience on the subject.

Once the IT maturity is assessed and the type of arrangement is decided upon, the organization can define their IT architecture. For this part, it is important to map out what is already in place. Then, the organization can determine where it wants to go and what this would look like. Again, this is based on the goals and objectives from the previous section. A recommended practice in this framework is the use of an iPaaS, or another form of integration platform. Such platforms and how they work are described in Section 3.3.3. One of the main benefits of such a platform is that it eliminates the need for point-to-point connections between applications, and thus agreements between the providers too. Such agreements bring a high degree of complexity to the system. This is further described in Section 4.4.3. Overall, an

integration platform provides the possibility of loose coupling the IT landscape, which makes it easier to manage the system.

Other elements to consider when creating the IT architecture are data, risk, and application management. As technical management – the management of physical servers and other hardware – is outsourced, it has less relevance in this architecture. For a large part, data management is covered by the integration platform. However, all these types of management can be supported by existing IT frameworks, like ITIL, COBIT, and ISO guidelines. For instance, the COBIT framework provides a set of control objectives and information criteria, like confidentiality, integrity, and availability (Gantz, 2014). These are all still relevant in the multi-cloud context. For risk management, such frameworks can be useful to identify and mitigate risks. A part of risk management is identity and access management. An approach to this can be role-based access in the system.

Application management in this context also contains some functional management. For this part, the organization should determine what it wants to achieve from the perspective of the end user. This can either be an employee, a customer, or another entity in the environment. From these choice, suitable cloud service providers can be selected. This is a typical best-of-breed approach, in which the organization procures the optimal solution for each line of service. In all these steps, the cloud office should be involved.

4.1.3 Contract level

The intra-organizational governance is now clear. From this point, the organization can determine what the governance and management structure is going to look like between them and their providers. This is the start of the inter-organizational part, and builds further upon the existing structure from the previous sections.

There is a number of requirements that the organization should consider to include in the contracts with the providers. As discussed before, a mediator can assist with this. First, the organization should determine the QoS requirements. These follow from the specified business objectives formulated in Section 4.1.1. The organization should assess what is needed in terms of service to attain their goals. This can contain elements like response time and availability. These elements also follow from the architecture that was designed in the previous section. These QoS requirements can optionally be complemented by QoE requirements. Such requirements are related to XLAs, which are discussed in Section 3.3.6. QoE focuses on the experience of the end user. A final set of requirements that should be included in the contracts are security requirements. These follow from the risk assessment and management discussed in the previous section.

For all of these requirements, the organization should have mechanisms in place to measure them. Again, this can be done in collaboration with the mediator. For service requirements, these can be KPIs for technical elements of the system. For experience requirements, an approach would be to do surveys with end users. From

a security perspective, penetration testing might be an option. This can again be done in compliance with existing IT frameworks. All of these requirements should be part of the SLAs with the cloud service providers. Monitoring can optionally be done by a mediator. An alternative to SLAs are XLAs. These can be used if the organizations deems the use of QoS requirements irrelevant in their context.

Another crucial point which should be included in all agreements is the division of roles and responsibilities. The point of contact from each of the cloud service providers should be clear, so that the organization knows where to go when things go wrong. The availability of this point of contact could also be taken into consideration. Responsibility and accountability should be clearly defined. In the end, it often takes a collaborative effort to solve certain issues. If there are no clear agreements, stakeholders might start pointing at each other over whose fault it is. In that case, effective collaboration is hard to achieve. A mediator might also assist in this. This can for example be observed in Case 2 (Section 3.2.2), where the mediator decided who is accountable for failure in each situation.

4.1.4 Relational level

The final part of the governance structure is on the relational level. Most of the elements discussed until now are black on white. This is already a substantial part of the governance structure, and supports collaboration and effective management in the multi-cloud environment. However, relationship management is another essential element. Good relationships result in trust, and vice-versa. More trust results in better collaboration. Building trust takes time, and therefore an organization must address this part of governance. Besides, if relationships are improved, it is often easier to reach out to the right contacts at a cloud service provider. This further stimulates collaboration, and can evolve to a partnership.

In this part of the inter-organizational governance, the cloud office comes into play again. It is their task to manage relationships with vendors. This can be done by planning frequent evaluations and meetings. Besides, they should think about the form of communications and how they can address issues in the right way. A simple e-mail might suffice, but does not necessarily build a solid relationship. Face-to-face meetings may be better suited for this purpose. A final element of relational level governance is expectation management. The formal part of this is already determined by contracts and agreements, but expectations can change. With proper expectation management comes transparency. This way, the organization will not be facing unpleasant surprises.

4.1.5 Overview

The previous sections have covered all elements of the framework. It starts with a solid foundation from within the organization, which translates itself to agreements and relationships in the domain of inter-organizational governance. With the right mechanisms and considerations, the framework provides a clear governance

and management structure. Applying these mechanisms ultimately leads to effective multi-cloud management, which is the main objective of this thesis. The most important mechanisms are a cloud office and integration platform. Those are also specifically related to the multi-cloud context. Furthermore, a clear division of roles is a crucial factor in the environment.

This division of roles should always be properly managed when a consultancy agency, a mediator, or an integrator are hired to assist in the process. It is important to avoid any overlap. For example, a mediator should not also be an integrator. This could result in a conflict of interest, as the mediator can provide themselves with more work. Therefore, one party having multiple roles should be avoided.

Coordination in the framework

The framework is called a coordination framework. This might seem counter-intuitive, as there is not necessarily a clear allocation of elements or stakeholders. However, applying the framework results in the right coordination within the multi-cloud environment, from the perspective of the organization using the multi-cloud system. Coordination Theory describes coordination as managing interdependencies (see Section 2.4.3) (Malone & Crowston, 1990). This is exactly what the framework implies. It builds a governance structure which aims to provide a grip for organizations to manage these interdependencies.

Furthermore, from an architectural point of view, applications and services are coordinated. For instance, they are coordinated by means of an integration platform. This entails communication between them, and how they are placed in the system. Besides, the position of stakeholders in the system is also determined, as their exact roles and responsibilities are defined. Overall, the framework provides a variety of forms of coordination. For these reasons, it can be called a coordination framework.

4.2 Application of the framework

The previous section describes what each element of the framework entails and how it should be interpreted. This section explains how the framework can be used and applied in a practical context. This consists of two questions: *Who* should use it and *how* it should then be used. The first part of this section provides a general overview of these questions. In the second part, a use case is presented to demonstrate the use of the framework.

4.2.1 A guideline for IT managers

In general, the framework is meant for organizations that want to use or are using multi-cloud. The goal of using the framework is to construct an effective governance and management structure within and around the organization. However, one should

note that the framework can be used as a guideline or roadmap, and is no guarantee for success. Every situation is different, and should be assessed accordingly.

In the introduction of this thesis, three main stakeholders are presented. These are the customer, the cloud service providers, and the multi-cloud platform provider. In terms of these stakeholders, this framework is meant for the customer that procures a multi-cloud system. The multi-cloud platform provider is the supplier of the integration platform. The role of the cloud service providers is clear.

There are two other stakeholders involved in this framework. These are the consultant and the mediator. The role of the mediator does not occur in the initial system analysis (Appendix A). However, the findings from the literature review in Chapter 2 show that the mediator plays an important role in many arrangements. Their task is to compensate for knowledge gaps within the inter-organizational governance structure. This means that they can assist the customer with relational or contractual governance aspects. The role of the consultant is to advise and assist the customer in the process of developing their intra-organizational governance structure. The difference is that the mediator holds an intermediary position between the customer and the cloud service providers, where the consultant does not deal with other stakeholders besides the customer. If the customer has much in-house knowledge on multi-cloud and a high organizational maturity, the consultant and the mediator may not be needed in that specific case.

So, from these five stakeholders, the framework presented in this chapter is most relevant for the customer. However, an organization can be quite large, and it can still be unclear who should use the framework. This should definitely be someone from the IT department. Preferably a manager, director, or CIO. They have the lead in the multi-cloud strategy, and can determine when to execute which step. Using the framework as a guideline, they can then arrange their governance and management structure in an effective way. A practical example of this is presented in the following section by means of a use case.

4.2.2 Use case: Effective multi-cloud management

This use case is meant to show how the framework applies in a practical setting. It follows Case 3, which is described in Section 3.2.3. In this case, the multi-cloud system is not effectively governed. Due to overlapping roles and unclear responsibilities, the organization experienced many difficulties. This use case demonstrates how these challenges could have been mitigated by using the framework.

The organization is an educational institution that is migrating a large part of their IT landscape to the cloud. They want to achieve optimal functionality within the system. Therefore, they choose to procure a best-of-breed multi-cloud solution. The organization does not have much knowledge on which cloud services are optimal for their wishes. It is already clear that they will need assistance from a third party in composing their system. However, before going head over heels into these questions, the organization uses the framework to approach this project step-by-step.

Service level

The first step for the organization is to decide on intra-organizational aspects on the service level. To approach this, the CIO decides to appoint three people as project lead. Together, they form the cloud office of the organization. This team consists of two IT managers and a member of the educational council. The latter member represents employees within the organization, and is up to date with their wishes. As a cloud office, their first task is to determine the BLOs of the multi-cloud strategy, and present their findings as a business case to the Executive Board. Such objectives cover the cost-effectiveness of this strategy, but also that they want to achieve optimal functionality within the system.

Besides the objectives, the cloud office is tasked with assessing the competencies and capabilities of the organization in this context. The IT managers know that they do not have the in-house knowledge to make a credible assessment of their own IT maturity, and decide to appoint a consultant to assist them in the second step of the framework. Furthermore, they decide who is responsible and accountable for different parts of the project. They expand the cloud office with a data lead and a security lead. The internal roles and responsibilities are now clear, along with the objectives. Based on the assessment of in-house capabilities, the decision is made to appoint a consultant.

Technical level

In the second step, the IT aspects of the arrangement are assessed. With the help of the consultant that was appointed in the previous step, the cloud office determines the organization's IT maturity. They conclude that this maturity is insufficient to manage and negotiate all contracts on their own. Therefore, the decision is made to appoint a mediator. It is important to note that the mediator is another independent stakeholder, and not part of the consultancy agency. Otherwise, the consultancy agency would be providing themselves with more work, which may cloud their judgement. This decision automatically leads to a mediated arrangement.

The IT managers within the cloud office then determine the architecture of their IT landscape. This is done in collaboration with the data lead, security lead, and consultant. Using existing IT frameworks, they make sure that all controls are in place to mitigate security and privacy risks. Furthermore, they decide to use an integration platform to connect all cloud services to each other. The data lead determines how data flows through the system, and which data this is. Furthermore, the cloud office decides which applications form the solution that the organization desires.

This concludes the intra-organizational governance structure. The cloud office regularly reports back their progress to the Executive Board, and makes sure that every stakeholder is involved in this process. Within the cloud office, roles and responsibilities are clear, along with who is accountable for which part of the system. Furthermore, the objectives of the strategy are formulated. This includes which services they need for optimal functionality, and how they should be integrated. From here, the

organization can look at the inter-organizational governance structure.

Contract level

The mediator plays a role in contract negotiations and monitoring between the three main stakeholders. In the previous steps, the customer has made their wishes specific. The BLOs formulated in step one state what they want to achieve with the system, while the architecture model from step two shows which technical services are needed to accomplish this. With assistance from the mediator, the cloud office determines which QoS requirements follow from the previous steps. They include KPIs on the uptime of the system, but also on security measures that follow from the risk assessment. Each lead in the project is accountable for the inclusion of requirements on their part. After a round of negotiations, these requirements are implemented in the SLAs between the customer and the cloud service providers, and the SLAs between the customer and the multi-cloud platform provider.

Roles and responsibilities are also included in the contracts. The decision is made that if a problem occurs, the mediator investigates who is accountable for this. Besides, the mediator monitors if the services meet the KPIs in the agreements. However, a joint effort is often required to approach certain problems. To support this, the cloud office is tasked with relationship management. This is addressed in the next step. To implement all cloud services and the integration platform, an *integrator* is appointed (see Appendix A). Again, this is a different party than the mediator or consultant. The integrator should be independent, as roles should not overlap. This is discussed in Section 4.1.5.

Relational level

The organization has a clear view on which services they use and why they use them, and contracts have been set up accordingly. They realize that collaboration remains important for a number of aspects. These include system failure, but also handling new releases. To manage these relationships, the cloud office decides to plan a quarterly face-to-face meeting with each cloud service provider and the integration platform provider. In these meetings, the representatives from the cloud office address how they have experienced the service, if any problems occurred, and what they would like to see in the future.

Furthermore, each cloud service provider has a designated point of contact that is dedicated to the organization. These people are always available to help out. Members of the cloud office can contact these points of contact by phone or e-mail. This can be also be for small questions and regular check-ins. The points of contact know who to approach within the organization of the cloud service provider. Still, when larger problems occur, the mediator is assigned to investigate the issue and to determine which stakeholder is accountable. They can also assist in resolving the issue.

Result

After applying the framework, the organization has a clear structure for governing their multi-cloud arrangement. The cloud office is accountable for management of the system, but also the relationships with the other stakeholders. The latter is approached by planning frequent meetings in which representatives of the cloud office can articulate their wishes. This is substantiated by clear BLOs, which gives the cloud office a foundation to build on.

A number of challenges is mitigated with this approach. Interconnectivity and interoperability are covered by the use of an integration platform. While this involves another stakeholder, it eliminates the need for complex agreements between multiple cloud service providers. Besides, it supports effective data management, as all data flows through this platform.

Security and privacy challenges are considered from the beginning. By appointing a security lead, there is always someone accountable for this part of the system. A risk assessment is executed to identify adequate controls within the system, with the help of a consultant. Implementing these requirements from the start can be classified as Security- and Privacy-by-Design. This reduces risk in later stages of the project.

The final challenge is collaboration. This is approached by setting up a clear structure for relationship management. Eventually, this results in trust between all stakeholders, which positively influences collaboration. The cloud office plays a vital role in this.

Added value

This use case is based on Case 3 from the multiple-case study. In that case, multi-cloud management was initially not effective. This lead to difficulties in the system, and the organization was not able to overcome certain challenges. The bottleneck in that case was the collaboration between all stakeholders.

This use case shows that these challenges can be approached together by applying the framework. This provides the organization with a guideline for developing a clear governance structure. This leads to effective multi-cloud management, as people know who to approach in every situation. Besides, it generates trust and mature relationships between all stakeholders.

Had the organization under study in Case 3 used this framework, they might not have encountered the difficulties that they faced. The elements that were missing in that case were clear BLOs, the presence of a cloud office, and a clear division of roles. Using this framework, these elements would have been included and multi-cloud management would have been more effective.

4.3 Composing the framework

The framework and how it can be applied are now clear. This section describes how the framework came about. This includes the links that it has to the findings of both the literature review (Chapter 2) and the multiple-case study (Chapter 3). This way, it shows the thought process behind the composition of the framework. This section is structured as follows. First, the goals of this thesis and how they translate to this framework are discussed. Then, the same goes for identified challenges, factors and requirements, and techniques and mechanisms in the multi-cloud context.

4.3.1 Goals

The main research question of this thesis is *How can multi-cloud systems be effectively managed within an organization?*. The objective is to answer this question by means of the framework presented in this chapter. It should provide guidance and clarity in the governance and management of multi-cloud systems.

From this perspective, the composition of this framework was approached. In the previous chapters, a variety of challenges, factors, requirements, and mechanisms was identified for this purpose. In the end, the framework provides a method for structuring governance and management within the multi-cloud context. This results in clarity when navigating through the different elements that play a role. By keeping these goals in mind, the framework is designed in the way that it is supposed to.

4.3.2 Challenges

The second sub question of the research questions aims to identify challenges in the multi-cloud management context. The literature review showed that integration is the overarching challenge. An important element of this is interoperability (Ardagna, 2015). Furthermore, security and privacy are issues that require attention (Akande et al., 2013). Most of this was confirmed by the multiple-case study. Three additional challenges occurred: data management, interconnectivity, and collaboration.

The framework is then designed in such a way that these challenges are addressed, and preferably overcome. This is done by considering factors and mechanisms that have been identified in this research. Interconnectivity and -operability are for example managed by implementing an integration platform. A part of data management is also addressed by this platform, as is discussed in Section 4.1.2. Besides, security and privacy are addressed by proposing potential mechanisms in steps 2 and 3 of the framework (technical level and contractual level, respectively).

The remaining challenge, collaboration, is also addressed by multiple aspects of the framework. Contractual level governance is proposed in such a way that it stimulates collaboration, and relational level governance is designed to further support it. Overall, composing the framework starts with thinking about these challenges and goals, and what is needed to mitigate them. Along with the overarching factors

of business (in the framework: *intra-organizational*) and inter-organizational governance, this provides a rough sketch of the framework. From there, it is possible to further investigate specific factors, and how they apply in this context. The factors and mechanisms that play a role in mitigating all these challenges are also deducted from Chapters 2 and 3. Their role in the framework is discussed in the following two sections.

4.3.3 Factors and requirements

The third research question focuses on the relevant factors within the multi-cloud environment. From the literature review, an extensive list of factors was deducted. This list is elaborated on in Appendix C. This also resulted in a number of potential mechanisms, which are discussed in the next section. Besides the list of specific factors, business and inter-organizational governance were identified as overarching factors. The roles of the different types of governance are visualized in the conceptual framework (see Figure 2.3). The link between the conceptual model and the coordination framework is immediately clear, as the different types of governance come back in the framework presented in this chapter.

However, the big question after the literature review was how to arrange these governance types in a multi-cloud environment. For this purpose, the list of factors from the literature review was compared to that of the multiple-case study in Section 3.3. Most challenges are also factor in the multi-cloud environment, like interoperability and data management. Other factors include risk management and organizational maturity.

These factors can then be translated to requirements, which answers research question 4. Requirements include a clear division of roles, formulated BLOs, and the appointment of a cloud office. These findings are then used to overcome the challenges from the previous section. They are translated to the framework by assigning them to the relevant level of governance. This way, all requirements and relevant factors are included in the framework. For some of them, it is still ambiguous how to manage them in the multi-cloud environment. Along the way, certain mechanisms have been identified. These mechanisms can help to make sure that the requirements are met. The next section addresses these mechanisms, along with their place in the framework.

4.3.4 Techniques and mechanisms

Four main mechanisms have been identified during this research. An integration platform, a cloud office, IT frameworks, and SLA/XLA. The first two are specific for the multi-cloud context. Existing IT frameworks provide a proven methodology for risk and application management, which is still relevant in a multi-cloud environment. SLAs (or XLAs) are also common in all IT practices. Still, the framework provides some elements which are required in those agreements from a multi-cloud perspective.

A cloud office is a mechanism that is first identified in the literature review. Prasad et al. (2014) propose a number of elements of such an office, like a chief cloud officer and a cloud management committee. In the analysis of the factors and mechanisms in Appendix C, these elements are grouped together to *cloud office*. This mechanism is confirmed by some of the participants in the interviews, who state that they have a similar mechanism in place. A cloud office can help in all stages of the process, and makes sure that the system is managed in a structured and clear way.

Kritikos et al. (2019) propose the use of a multi-cloud management platform. The multiple-case study shows that this is a good practice in a multi-cloud setting, which mitigates many challenges, factors, and requirements. It helps with interoperability and data management, and simplifies a part of the environment. This makes it easier to achieve the desired functionality, which is an indication of effective management. This is the main goal of the thesis, and therefore, the integration platform must be included in the framework.

In the end, these mechanisms and techniques help to implement factors and requirements in the governance structure of a multi-cloud environment. This is useful for handling the challenges that arise in such a context. All elements of this process are captured by the framework, which helps to attain the ultimate goal of this thesis: effectively managing multi-cloud systems.

4.4 Considerations

This section discusses some considerations for organizations working with a multi-cloud strategy. This also includes some possibilities that are not covered by the framework. The goal of this section is to provide a nuanced view to the reader, and put things into perspective. Besides, every situation is different and should be assessed accordingly. There is no single best practice, and this section aims to describe why.

The first part of this section discusses the differences between situations. Then, the cost-effectiveness of multi-cloud arrangements is addressed. This is followed by a comparison of different integration approaches. The final part of this section describes how certain multisourcing arrangement models associate with relational governance.

4.4.1 A nuanced view on multi-cloud

The framework that is presented in this chapter describes general components of a multi-cloud governance structure. This is done in an effort to make the framework applicable in many situations. However, each situation is different, and should be assessed accordingly.

For instance, a medical institution might have a small IT department. If that organization wants to use a multi-cloud system, they would need a lot of outside help. They can approach a consultancy agency from the start to help them in this process. In this case, it would be the consultants who would be using the framework. A professional

services firm with much in-house knowledge could be using the framework for their own organization. As they have many in-house capabilities and high IT maturity, they might skip the steps of appointing a consultant or mediator.

This shows that the framework can be applied in different ways and be used by different entities. There are many possibilities when using multi-cloud. Think of the difference between library-based and service-based systems. While the framework goes a long way in generalizing the findings from the literature review and the multiple-case study, it is not applicable in every situation. As with most concepts, there are exceptions to the rules. Therefore, this framework is no guarantee for success, but it can help in guiding an organization in developing their governance and management structure.

4.4.2 Cost-effectiveness in multi-cloud arrangements

One of the advantages of multi-cloud is that an arrangement of different services if often cost-effective. This is often used as another metric for effectiveness of IT governance (Weill & Ross, 2005). This thesis focuses more on asset utilization, but cost-effectiveness is an element that should not be forgotten.

While a multi-cloud solution may seem cost-effective, it is important for an organization to look at additional costs. Alpar and Polyviou (2017) argue that hiring external parties may offset the cost-effectiveness of multi-cloud. However, multi-cloud should not be approached in a way where knowledge is lacking. Therefore, external parties are often required to create a successful and effective multi-cloud system.

The organization should be aware of these costs. Besides, an iPaaS solution may result in additional costs too. While this does not change the framework or how it applies, it must be considered when creating a multi-cloud strategy. This is also one of the goals of the intra-organizational service level governance in the framework. By assessing competencies and capabilities, an organization can decide which approach is feasible.

4.4.3 Integration of services

The overarching challenge in the multi-cloud context is integrating different services, as has been derived from the literature review and confirmed by the interviews. Clear integration is crucial for matters such as interoperability, data management, and security. The framework proposes to approach this with an integration platform. However, there are other possible types of arrangement. For instance, Bapna et al. (2010) proposed the use of OLAs to stimulate collaboration between vendors. This section investigates how this could apply in the multi-cloud context, and how that differs from an integration platform.

Integration platform

A good practice presented during the interviews is the use of an integration platform. This eliminates the need to manage the complex relations between different cloud vendors. Each cloud service or application is connected to the platform through its respective API. The platform standardises the received data and transforms it into the right format for the other application. A simplified model of how this works is shown in Figure 3.1.

An alternative coordination approach

In order to effectively manage multi-cloud systems, organizations need to clearly orchestrate the cloud services they use for their applications. The organization needs to know which services they want to use and what they want to use them for. This follows from the BLOs formulated on the intra-organizational service level.

Problems that arise in the multi-cloud environment are insufficient interoperability and compatibility. Causes of this can be vague agreements between the organization, and no agreements between cloud providers. To mitigate this, mechanisms like SLAs and OLAs can be used. Following the models of forced coopetition by Wiener and Saunders (2014) (Figure 2.2) and service-based multi-cloud systems (Figure 2.1), it becomes visible where these mechanisms should be implemented. This is displayed in Figure 4.2.

The figure shows the point-to-point connections between the different cloud services. Note that this could also apply in a library-based system. In that case, cloud services should be renamed cloud applications, which connect to the organization as a whole. For the purpose of simplicity, these varying configurations will not be further discussed.

Still, it is interesting to look at all different connections in such a system. There are many agreements, and data flows to all stakeholders. For instance, provision of service also includes the data. To keep things clear in the model, such additional, specific connections have not been drawn. One could also ask the question of how the organization is going manage the OLAs between cloud providers.

A comparison

Comparing the models in Figures 3.1 and 4.2, it becomes apparent that an integration platform produces a much cleaner solution in terms of data and agreements. Besides, the point-to-point model has not been observed in the multiple-case study, and therefore only has theoretical value in this thesis. Considering the challenges of interoperability, interconnectivity, and data management, the integration platform seems a much more suitable solution. This section shows the reasoning behind it, and why the theoretical alternative is not recommended in the framework.

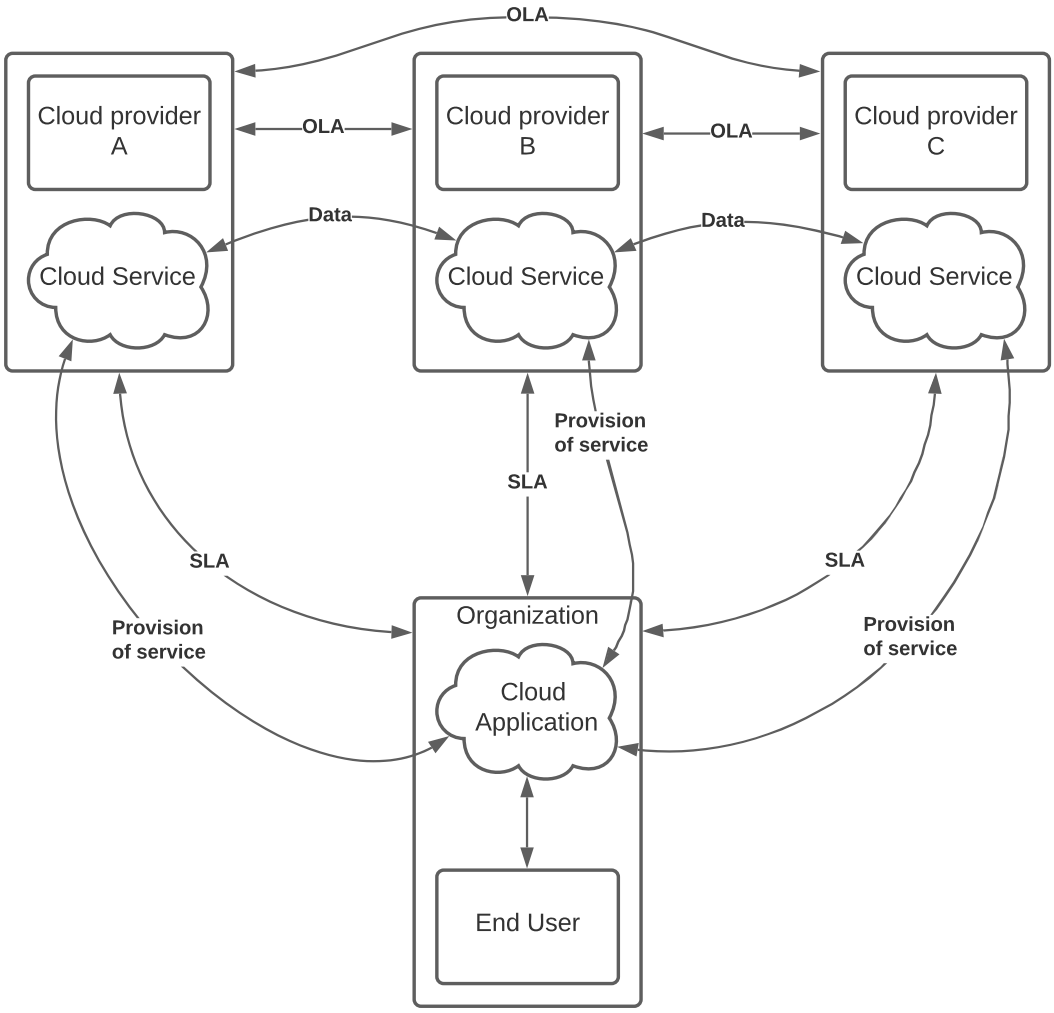

Figure 4.2: Agreements and interactions in a service-based multi-cloud environment

4.4.4 Partnership-oriented model

The importance of clear relational governance has been stressed throughout this thesis. The work by Plugge and Bouwman (2018) showed this importance in multisourcing arrangements. The coordination framework presents an approach to achieve this in multi-cloud systems. Organizations should keep in mind that relationships are often build on trust. This takes a while to establish, so an ad-hoc environment where cloud vendors come and go is not beneficial to this cause. The approach of the framework is mostly focused on the relationships between the organization and the cloud providers. However, relationships between other stakeholders are not addressed.

One way to approach that part of relational governance is the partnership-oriented model presented by Schmidt and Suomi (2018). This model follows from the forced coopetition model by Wiener and Saunders (2014). The difference is that in the partnership-oriented model, the competition aspect fades away and the cloud providers

make alliances to provide an optimal solution. Again, this could not happen in an ad-hoc environment. From these partnerships, trust emerges. This could in turn benefit organizations that want to procure both their cloud services, as these services should seamlessly work together. This would also reduce the need for OLAs, described in the previous section.

However, such partnerships may not be as effective as they might seem. In Case 3 (see Section 3.2.3), two cloud services were proposed that should easily work together. This was supported by the fact that the providers of these services also had a partnership. Nonetheless, this did not turn out as expected. The degree of standardization and interconnectivity were low, which caused the result to be insufficient.

Because the partnership-oriented value was not observed as a successful practice in the multiple-case study, it only holds theoretical value in this thesis. Therefore, it has not been included in the framework.

Chapter 5

Evaluation

This chapter describes the evaluation of the framework and results presented in this thesis. This is done for a dual purpose. First, the evaluation should show if the findings of both the literature review and the multiple-case study are generalizable. This is a part of external validation and would give the framework a more substantiated foundation, as it is based on those findings. The second purpose is to evaluate the framework itself. This should cover the framework's usability, advantages, and disadvantages.

The first section of this chapter describes the approach and methodology to this evaluation. The second part discusses the results of the evaluation, and what they imply for this research. The second part is concluded with a brief discussion on the applicability of the findings in different situations. This is meant to put things into perspective and provide a nuanced view on the results of this thesis.

5.1 Evaluation approach

The evaluation of both the findings and the resulting framework are approached by conducting an interview with a subject matter expert. This expert has much experience with cloud integration. He has seen a wide variety of organizations that work with such systems, and can thus say if the findings from this thesis are generalizable. This provides external validity to the findings.

As stated in the introduction of this chapter, the interview is divided into two main parts. The first part focuses on the findings of this thesis. That is, all answers to the sub questions stated in Section 1.4. As these answers form the foundation of the framework, their accuracy also determines the accuracy of the framework. This means if the answers are generalizable, and is a part of external validation (Yin, 1994). The second part of the interview discusses the framework. This further assesses the accuracy, but also determines the usability of the framework in a practical setting. This should also establish the added value of the framework.

A final addition of the interview will be a brief discussion on the usability of the findings and the framework in a service-based multi-cloud environment. As the multiple-case study did not present any relevant findings on service-based systems, this discussion has more of a theoretical value. The questions for these interviews can be found in Table D.2, in Appendix D.

5.2 Evaluation results

This section describes the results of the evaluation. It is structured in the same way as the interview. So, the first section describes the evaluation results on the findings of this thesis. This is divided into a paragraph on validation, a technical part, and a part on governance and management. The second section describes the evaluation of the framework. The final section presents a brief discussion on the applicability of the findings in a service-based multi-cloud system.

5.2.1 Evaluation of the findings

External validation

Internal and external validity have been discussed in Section 3.4. During the evaluation interview, an additional step in external validation is taken. External validation describes to what extent the results of this research are generalizable (Yin, 1994). In Chapter 3, this is approached by replication. This additional step is by asking the subject matter expert explicitly about the generalizability of the findings.

This specifically goes for the findings on integration platforms. Therefore, Question 1 of the evaluation interview is:

Is an integration platform always used for cloud integration?

The answer to this question determines to what extent the use of an integration platform is generalizable. Similar questions are asked about other concepts, like factors and challenges. The following two paragraphs address the answers to these questions, and thus the external validity of the findings.

Technical aspects

According to the subject matter expert, interconnectivity is the largest challenge in cloud integration. An iPaaS solution is usually the best answer to this problem. However, it does not necessarily reduce complexity. An integration platform moves this complexity and centralizes it at one point. This does help the organization, and the platform indeed functions like a power strip. This also supports clear data management. It is important to include a generic data layer to the platform. Otherwise, the connections would still be point-to-point. A note on this is that it is feasible for organization to form point-to-point connections if they are only using two applications. In that case, an integration platform would be redundant.

Compared to a traditional ESB, an iPaaS solution actually offers a lot more. Where a traditional ESB only transports a message from one system to another, an integration platform is able to transform and process data. From that perspective, it plays a much more proactive role in the IT environment.

Except for point-to-point connections, there are no other tools or arrangements for the integration of cloud services. Therefore, an integration platform is definitely a suitable approach for the framework. Again, this also influences the quality of data management, which is indeed an important factor in the multi-cloud context.

Governance and management aspects

IT maturity is definitely an important factor to assess at the start of a multi-cloud project. Along with the scale and the intended costs, this can shape the overall multi-cloud strategy. When initiating such a project, it is also crucial to appoint people within the organization to certain roles. This is covered by the mechanism of cloud office, and the factor of clear role division. Working with such an office also results in trust, which makes collaboration easier.

Looking at contracts and agreements, XLAs are an upcoming trend. Such agreements are quite novel, but also progressive. Nowadays, it is often hard to exactly measure QoS requirements, due to huge amounts of data and services. From that point of view, XLAs may be better suited. They are experience-driven, which is a growing element of modern IT solutions. Still, it is not easy to quantify and monitor XLAs either. In the future, it may be a good alternative to the traditional SLA.

A mediator can assist in many ways in such arrangements. Still, it is crucial that their role does not overlap with any other roles. This is also discussed in Section 4.1.5. Furthermore, their role should be phased out in the course of time. As the organization acquires more knowledge and experience, the need for a mediator gets smaller. This is in line with the findings of this thesis.

Traditional IT frameworks do have a part to play. They still cover many aspects of IT governance and management which are still relevant in the cloud context. Therefore, it is the right conclusion to include these in the framework as a potential mechanism.

5.2.2 Evaluation of the framework

This section describes the advantages and disadvantages of the framework, and evaluates its usability. This is started by looking at the different elements of the framework and a brief discussion on the shortcomings of the framework. The final two paragraphs state its general advantages and disadvantages.

The subject matter expert agrees that performing a maturity check and appointing a cloud office provide a solid foundation and are a good first step of the framework. In their experience, it is crucial to have everything on the enterprise level in order.

This framework supports that, but is not necessarily the only framework to do so. However, it is an essential part and should therefore be included.

It is important to assess the impact of a multi-cloud strategy on the organization. While this is partly covered by the first two steps, it could be elaborated upon. The authority to make decisions is also an important responsibility that should be assigned. This is part of dividing internal responsibilities, but could also be described in a more extensive way. If this responsibility is not appointed to someone, it can become difficult to govern the multi-cloud arrangement.

From a perspective of usability, the framework has added value because it triggers to think about multi-cloud in an innovative way. This can provide a grip for managers within an organization. This is also what the framework is meant to do; it should function as a guideline to create a clear structure for governance and management of the system. This is a clear advantage of the framework.

A disadvantage is that the framework mostly focuses on the business perspective of managing multi-cloud. This is a logical consequence of this research, as this thesis is written from an organizational point of view. However, this makes the framework incomplete, as there is also a technical side to the problem. To include this is beyond the scope of the thesis, but it would make the framework more substantiated.

5.2.3 Discussion

During the evaluation, there was a discussion on service-based multi-cloud systems and on forced coopetition. As no service-based solutions were found in the multiple-case study, knowledge on this remained purely theoretical. The same goes for forced coopetition. Therefore, these matters were discussed, as the interviewees might have experience with them.

Service-based multi-cloud systems are more common than this research shows. However, they are often on a higher level. For instance, the Salesforce platform is a service-based multi-cloud solution. An organization using Salesforce may be aware of this, but will probably never notice it as they procure a Salesforce application as a single SaaS solution. In such service-based systems, it is hard to say if an integration platform would result in effective management. This is different in every scenario, and should then be assessed. Still, building such solutions requires tremendous effort, and would require much technical knowledge.

Forced coopetition is not so common. Although partnerships between different providers do occur, they are rarely forced by an organization looking to procure a specific solution. Therefore, these findings are still mainly hypothetical.

Chapter 6

Conclusions

This thesis was written as an exploratory study on the governance and management of multi-cloud computing. To investigate this, a literature review and a multiple-case study were performed. This resulted in a framework that should guide the process of governing multi-cloud systems. This framework was evaluated by subject matter experts, along with the findings of the literature review and the multiple-case study. This chapter is structured as follows. First, the research questions will be repeated, along with the answers to them. Then, the resulting framework will be briefly discussed. The final section addresses the implications and recommendations for future research.

6.1 Research questions

The objective of this research was to explore factors and mechanisms that are relevant in the multi-cloud context. These findings should result in a framework for effective multi-cloud governance and management. This led to the main research question of this thesis:

How can multi-cloud systems be effectively managed within an organization?

Effective management in this case is defined by the degree of asset utilization. That addresses the degree to which the organization using the multi-cloud system has achieved the desired functionality. To answer this question, four sub questions were formulated. The first question of these is:

What are multi-cloud systems?

This question is answered by the literature review, which provided a definition that is used throughout this thesis. Multi-cloud systems are systems where multiple independent public clouds are procured from different cloud service providers. This can be either library-based or service-based, where the former combines multiple cloud applications, and the latter combines different cloud services as components of one application. After defining multi-cloud systems, the other three sub questions

were answered by both the literature review and the multiple-case study. The second sub question is:

Which challenges are encountered when managing multi-cloud systems?

From the literature review, it was deducted that the overarching challenge is integration. Coordination of services is also an element, and refers to Coordination Theory, which is applied in this research. The challenges that were identified are interoperability and -connectivity, security, privacy, data management, and collaboration. The resulting framework aims to overcome these challenges. To do that, factors and requirements had to be identified. This is covered by the remaining sub questions, which were also answered by the literature review and the multiple-case study. The third sub question is:

Which factors influence the quality of multi-cloud management?

Broadly speaking, the most influential factors are intra- and inter-organizational governance. In the literature review, intra-organizational governance is called busines governance, based on the work by Prasad and Green (2015). These types of governance can be divided into multiple levels; the service, technical, contractual, and relational level. These are all implemented in the framework. Specific factors within these types are risk, trust, relationship, and data management, security and privacy, interoperability, and organizational maturity. Some of these have overlap with the challenges, but play a crucial role in managing multi-cloud systems. The last sub question aims to deduct the requirements for multi-cloud management from the previous questions, and is formulated as follows:

What are requirements for effective management of multi-cloud?

The requirements that follow from the previous questions have some overlap with the factors and challenges. This is only logical, as the requirements are deducted from them. The requirements are a clear division of roles, clear, feasible contracts and agreements, clear communication, formulated objectives, and proper data management. Besides, the multiple-case study showed that the appointment of a cloud office and the use of an integration platform are good practices to effectively manage multi-cloud systems.

Together, these challenges, factors, and requirements form the foundation of the ultimate framework. With this framework, organizations can create a governance and management structure to effectively manage multi-cloud systems. A complete and nuanced answer to the main research question is difficult to formulate, as there are many intricacies involved. Still, a two-sentence summary of the framework may provide some insights. To effectively manage multi-cloud systems, an organization should first structure their intra-organizational governance by clearly formulating objectives, dividing roles, and creating their architecture. This foundation should then translate itself to clear agreements and mature relationships in the domain of inter-organizational governance. A somewhat broader perspective on the framework is provided in the next section.

6.2 Framework

The framework in Figure 4.1, Chapter 4, aims to provide guidance to organizations in managing their multi-cloud environment. It is structured as follows. First, intra-organizational governance, consisting of the service and technical level, should be in place. Then, inter-organizational governance, consisting of the contractual and relational level, can be arranged.

On the service level, BLOs must be formulated, competencies and capabilities determined, and internal responsibilities appointed. Besides, a cloud office should be set up to guide the process. Then, the technical level governance structure can be arranged. This consists of assessing IT maturity, deciding on the type of arrangement, and defining the IT architecture of the system. Elements of this are risk, application, and data management. Existing IT frameworks can assist in this. Furthermore, the use of an integration platform is recommended. Based on the IT maturity of the company, a mediator can be appointed.

The second part of the framework aims to arrange the inter-organizational governance structure. This starts at the contract level. Requirements on different levels follow from the objectives and architecture defined in an earlier stage of the framework. Besides, roles and responsibilities should be clearly defined in the contracts. The final part of the framework addresses relational level governance. Relationship management is an important factor for which the cloud office is responsible.

Still, there is no best practice and every situation should be assessed accordingly. This framework can then be used as a guideline to succesfully manage multi-cloud systems.

6.3 Future research

Some suggestions for future research have come to light during this thesis. An evident opportunity for future research is to apply this framework in a practical setting. Although it has been positively evaluated by subject matter experts, it has not yet been tested. A test in a practical setting could better determine the usability of the framework.

Another interesting point is the use of XLAs. This is a current trend which has not yet been studied on a large scale. The applicability of such agreements in multi-cloud is interesting, but the use in general IT management may provide insights in the shift towards experience-driven IT systems.

Furthermore, the use and management of service-based multi-cloud systems remains theoretical after this thesis. Research in a practical setting may provide useful insights, especially from an organizational perspective. One could even try to apply the framework from this thesis in that context, which would make the circle of this thesis round.

Chapter 7

Discussion and reflection

This chapter contains a discussion on the results of this thesis and addresses its limitations. Furthermore, it describes the relevance of this research from both a managerial and an academic perspective, and how this thesis fits into the Management of Technology curriculum. Besides, a personal reflection on the process is included.

This chapter is structured as follows. First, the limitations of this research are discussed. This goes into the research methodology and how it was executed. The second part discusses a number of findings of this research and puts them into perspective. This is followed by a discussion on the relevance of this thesis. The final part of this chapter is a personal note to conclude this thesis.

7.1 Research limitations

For this research, the first step was performing a literature review. This was followed by a multiple-case study, in which the method for data collection consisted of doing interview at organizations using multi-cloud systems. This resulted in answers to the sub questions. Based on these results, a framework was constructed for effective multi-cloud governance and management. This framework was then evaluated by interviewing subject matter experts. This approach has some limitations, which are discussed below.

First of all, there is a limited amount of cases that are analyzed. This was due to the fact that it was difficult to find organizations that met the requirements to be selected, and were willing to participate in this research. The small number of organizations using multi-cloud further emphasizes the need for this research. Still, this resulted in a limited amount of interviews. To overcome this, subject matter experts were interviewed in order to generalize certain findings. Another limitation of the interviews is that they are one-sided. For each case, only one interview has been performed. This can result in a biased view. Again, evaluating the results with subject matters could straighten this out. However, in the evaluation interviews, there exists the danger of reflexivity. This means that the participant gives what the interviewer

wants to hear. Questions were formulated as objectively as possible and participants were encouraged to give their own view, in order to minimize this risk.

Furthermore, the evaluation is quite simple, and thus limited. While the results to the research questions may have been confirmed, the discussion on the usability and accuracy of the framework was purely hypothetical. A good next step would be to apply the framework in a practical setting. However, that is beyond the scope and possibilities of this thesis. Therefore, it is recommended as future research to investigate this. Organizations are free to use the framework to create, evaluate, or improve their current governance and management structure. Other scholars are also encouraged to investigate the application of this framework in a practical setting.

7.2 Discussion on the findings of this thesis

The literature review presented two forms of multi-cloud: service-based and library-based. While multiple companies are using a library-based multi-cloud strategy, it is hard to find organizations that use a service-based multi-cloud system. That means that a single application is running on multiple cloud platforms. The question arises: *Why are organizations not doing this?* It can be because of the complexity, or because of the extensive knowledge that it requires. This was also indicated in the evaluation of the results of this thesis. Service-based multi-cloud solutions do exist, but are hard to find or are a high-level service themselves.

Another explanation for the absence of such arrangements might be that they are not beneficial at all. If an organization uses multiple platforms to run a single application, it might eliminate the unique strengths of these platforms. This is argued by Quinn (2020), who says that using multi-cloud is using the "lowest common denominator between systems". This view may be a bit negative, but it does put up a good point for discussion. In views of this research, the statements by Quinn are not substantiated, especially not in a library-based multi-cloud set-up. From a theoretical perspective, this also goes for service-based systems, but that claim is harder to support with the lack of a relevant case in the multiple-case study.

An additional discussion point is on the integration platform. While an integration platform is recommended as a good practice, it may not be beneficial for every organization. As the evaluation displayed, some organizations may only use two applications. In that case, direct point-to-point connections may be feasible, and an integration platform redundant. Furthermore, there may be one disadvantage to using an integration platform. One of the benefits of working with a multi-cloud system is that it decreases vendor lock-in and increases flexibility. However, when using an integration platform, there is actually a vendor lock-in at the iPaaS provider. The only way to get around this is by building the platform yourself, which would require much technical expertise. Still, the vendor lock-in at an iPaaS provider is much smaller than the vendor lock-in at a cloud service provider, as the integration platform does function as a power strip.

Finally, it should be noted that the framework presented in this thesis is no guarantee for success. While it presents good practices and can definitely be used for developing a governance structure for effective management, it does not ensure this. As stated before, every situation is different and should be assessed accordingly. One should be aware of this when using the framework.

7.3 Relevance of this work

This section describes the relevance of this thesis, both in the managerial and the academic context. This also entails why this thesis fits into the Management of Technology curriculum. This is due to the fact that this thesis covers many aspects. It describes the technical subject of multi-cloud in a corporate setting, and discusses this from an organizational and managerial perspective. First, the managerial relevance of this thesis will be described. Then, the academic relevance is discussed.

7.3.1 Managerial relevance

This thesis provides a framework for effective multi-cloud management. From a managerial point of view, this framework is useful for setting up a governance and management structure within an organization. As it covers both technical and organizational elements, it can be advantageous on multiple levels in an organization.

7.3.2 Academic relevance

This thesis discusses both the technical and organizational aspects of multi-cloud, and combines these aspects with multisourcing theories and Coordination Theory. This way, it fills a part of the knowledge gap described in Section 1.2. Furthermore, the theoretical element of this thesis is tested in a practical environment, providing insights in the theory around multi-cloud. Therefore, this work is also academically relevant.

7.4 Personal reflection

Looking back at the process of writing this thesis, I am quite content with how everything went. As always, there are some aspects that I would have approached differently with the knowledge that I now possess. One of the things that I have learned is that it is much harder than I expected to arrange interviews with people within organizations. Before this project, I was not aware of how to approach this in the fast-moving corporate world. Luckily, I was assisted in this by my colleagues at PwC. If I would do another project like this, I would start much sooner with arranging these interviews. For this project, I started with this around one and a half month in advance. Still, I encountered difficulties, so I would advise everyone to start even sooner.

This thesis is written in times of COVID-19. When I started this research, the pandemic was already around for almost a year. I was already used to the situation, but I think it still made a difference in writing this thesis. I did have the opportunity to go to the office now and then, but most of the work has still been done from home, and almost every meeting was online. A nice exception to this was a meeting with Haiko, where we discussed my thesis during a walk around the centre of The Hague. Due to the online setting, it was often difficult to come in contact with the right persons for this thesis. This may have been a factor in the challenge of finding participants for the interviews.

Looking back at this thesis as a whole, I am mostly proud of the result. I have always liked the combination of organizational and technical aspects, and I think this is definitely reflected in this thesis. For me, this feels like the best way to conclude my education and say goodbye to the student life.

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Appendix A

System analysis

This appendix describes the institutional context of the problem addressed by this thesis. A number of models of the system are created to provide insights on the current relations between actors, the flow of information, and the positions of all stakeholders. To do this, certain existing models from the literature are used as a basis. These also include actors and their roles in the multi-cloud environment.

A.1 The multi-cloud ecosystem

In order to get an understanding of the multi-cloud ecosystem, it is interesting to explore the current state of research on the general cloud computing ecosystem. The results from this exploration can be used to create a list of stakeholders and roles, and models of the system.

A.1.1 Stakeholders and their position

Early work on the cloud computing ecosystem presents a generic value network (Böhm et al., 2010; Leimeister et al., 2010). Böhm et al. (Böhm et al., 2010) initially identify six major roles in this ecosystem, in which they make a distinction between the types of service providers. However, these types are a composite actor along with *Market Platform* which is perceived as the cloud computing service by the consumer. These roles and their meanings are listed below.

- **Application Provider** - The provider of SaaS services.
- **Platform Provider** - The provider of PaaS services.
- **Infrastructure Provider** - The provider of IaaS services.
- **Consumer** - The customer who acquires the cloud computing services.
- **Market Platform** - The marketplace where consumers can find suitable cloud services.

- **Aggregator** - The aggregator creates or bundles multiple cloud services into one solution. In the case of multi-cloud, this is what the customer wants to do themselves. An aggregator can also add value on top of an existing solution. Some aggregators compare cloud services, so that customers can find the best fitting solution. This is similar to a market platform, but also a cloud broker.
- **Integrator** - The integrator helps with implementing cloud services at the customer and migrating their on-premises resources to the cloud. For the remainder of this appendix, this role will be named the *system integrator*. This is because there also exists a *cloud service integrator*, which is a specific kind of aggregator.
- **Consultant** - The role of the consultant is to advise the customer about cloud computing offerings, and what is suitable for their organization. Besides, they can also assist the cloud providers with tasks like analyzing the market.

Building further on this value network, Floerecke, Lehner, and Schweikl (Floerecke et al., 2020) present an extensive model of the cloud computing ecosystem. They have made multiple iterations on this model, which counts 31 different roles in the final version. For this thesis, some of these roles are more important than others. Therefore, eight other roles are taken into consideration in addition to the roles above. Besides, the distinction between types of service providers is discarded. In light of this thesis, this distinction does not have to be made as all cloud offerings are considered for possible multi-cloud systems. The eight additional roles are the following:

- **Multi-cloud platform provider** - This provider develops platforms which can link cloud services from multiple providers, and provisions a unified API. This can be seen as a PaaS offering, but also as a form of cloud service aggregation. Due to these nuances, this provider is not generalized as a cloud service provider.
- **Auditor** - The entity that makes assessments on any party in the ecosystem. This is often at the customer or cloud service provider, but can also be at other actors.
- **Software vendor** - This can either be an indepedent software vendor who develops and tests SaaS solutions, or a virtualization software vendor who develops virtual machines, which are often the backbone of IaaS services.
- **Physical infrastructure provider** - The entity that provisions the actual data centers.
- **Hardware developer** - The vendor who develops the hardware behind the infrastructure.
- **Standard developer** - This is an actor who influences the whole environment, and develops and promotes standards like TOSCA and CAMP (see Section 2.3.2.
- **Research institute** - This can be a source of innovation in technology and theory.

- **Open source community** - This actor develops and shares cloud initiatives, applications, and experiences. This can potentially be useful for involved organizations.

Note that some of the roles can have some overlap. A cloud service provider might also be a marketplace operator, or operate their own physical infrastructure. Each one of the stakeholders above has a position in the ecosystem. Along with that comes power and responsibilities. In order to prioritize these stakeholders, a power/interest grid is developed, which can be found in Figure A.1.

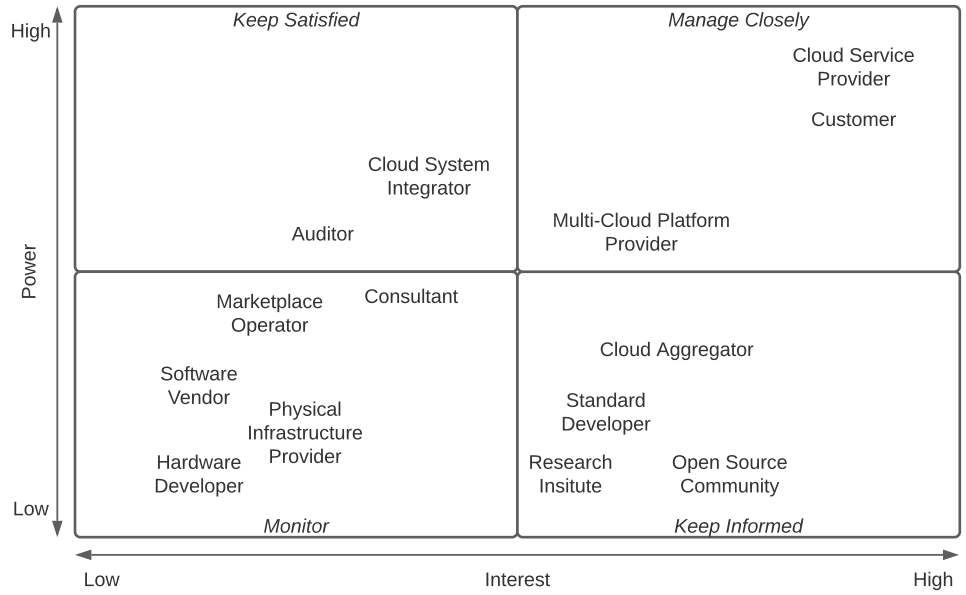

Figure A.1: Power/Interest grid for the multi-cloud ecosystem

Figure A.1 shows that the cloud service providers and the customer are the most important stakeholders in the multi-cloud context. They have the most interest and power in this case, and are highly interdependent. Three comparable actors with quite some power and interest are the multi-cloud platform provider, the cloud system integrator, and the cloud aggregator. As described before in this section, the multi-cloud platform provider is a kind of cloud aggregator, but also has some characteristics of a cloud service provider. The cloud system integrator has significant power as they perform the whole process of implementation. The cloud aggregator has a bit less power, but more interest, as they provide multi-cloud solutions themselves. However, these solutions still have to be bought and implemented, and therefore they hold less power.

The three environmental actors have a lot of interest in this case, but not too much power. The standard developer has slightly more power, as their standards could influence cloud service offerings and their interoperability. One actor who also has some power is the auditor, as they are certified to determine if either the customer

or cloud service provider has enough controls in place to safely operate the multi-cloud system. Still, the auditor plays a supportive role in this context. The remaining stakeholders are less involved in the complexities of this problem. Most of these have either a supportive or underlying role.

A.1.2 Multi-cloud ecosystem model

Following the actor analysis in the previous section, it is interesting to visualize flows of services and information in this ecosystem. This can help further understanding the problem, and where tensions occur. Based on the findings in Section A.1.1, a model which shows the flow of services is developed and presented in Figure A.2. This model is based on the work of Floerecke et al. (Floerecke et al., 2020).

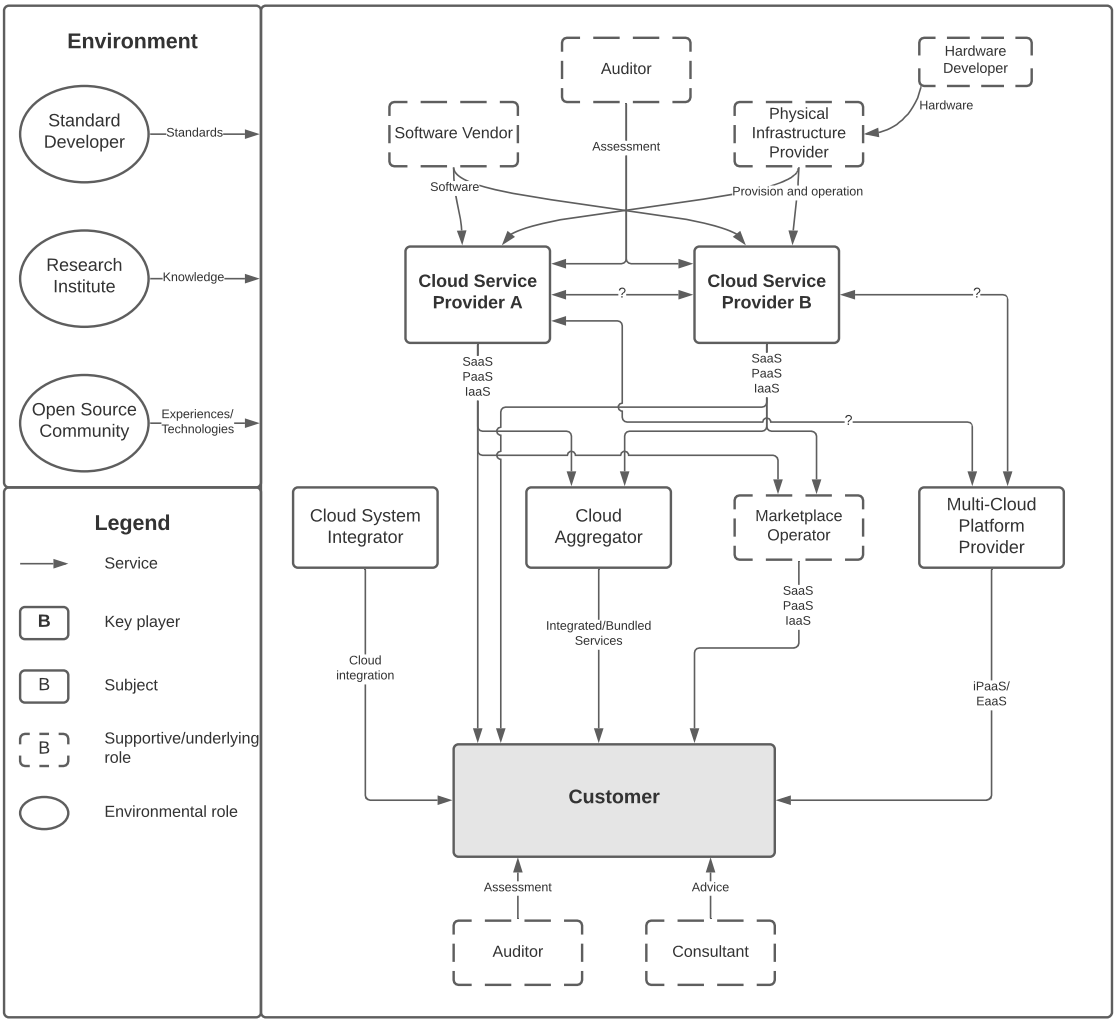

Figure A.2: Flow of services in the multi-cloud ecosystem

As stated before, some roles in this system can overlap. A cloud service provider can choose to provide and operate their own physical infrastructure, or run their own market platform. Still, other cloud service providers can use this platform to sell their applications in the form of SaaS. Another point worth noting is that the role of cloud aggregator can, in some instances, be skipped. This occurs when the customer procures cloud services directly from the cloud service provider.

The differences in the roles are displayed by the legend. Key players are the cloud service providers and the customer, which also follows from the power/interest grid (Figure A.1). Subjects are actors who are directly involved in the context of multi-cloud systems, but are not key players. They are not key players because their services are not essential. For example, the customer can integrate cloud services on their own, if they have the in-house knowledge to do so. This would make the cloud system integrator dispensable.

The service provided by the multi-cloud platform provider is difficult to label. As described before, it could be seen as an (integration) PaaS offering, which would therefore be labeled iPaaS. However, some providers call it *Environment-as-a-Service* (EaaS). Either way, what they provide to the customer is a kind of integration hub to connect the customer's cloud services.

Some flows are still unclear. This could be part of the cause of some of the problems addressed by this thesis.

Appendix B

Search description of the literature review

Table B.1 shows the specific searches that have been done for the literature review, including the number of results per database. The limitation is defined as follows. SUBJ, Busi stands for *Subject Area: Business, Management, and Accounting*. Note that Google Scholar does not provide the possibility to filter on subject area. Hence, there are no values for these searches in that database.

		Database		
Searches	**Limitation**	**Scopus**	**Web of Science**	**Google Scholar**
Direction 1				
"cloud computing" AND (management OR governance)		21608	742	603000
"cloud computing" AND (management AND governance)		340	4	65800
cloud computing AND governance		768	39	132000
cloud computing AND governance	SUBJ, Busi	114	4	N/A
Direction 2				
"multi-cloud" OR multicloud		1706	635	16500
"multi-cloud" OR multicloud	SUBJ, Busi	42	6	N/A
("multi-cloud" OR multicloud) AND (terminology OR taxonomy)		22	1	3460
("multi-cloud" OR multicloud) AND platform*		364	29	11300
("multi-cloud" OR multicloud) AND containerization		8	0	881
("multi-cloud" OR multicloud) AND tosca		24	3	901
("multi-cloud" OR multicloud) AND "cloud broker"		42	3	1090
Direction 3				
"IT multisourcing"		11	3	61
IT AND multisourcing AND management		19	0	20600
coordination AND "IT outsourcing"		36	0	12500

Table B.1: Literature search description and results

Appendix C

Factors and mechanisms

From the literature review, a variety of factors and corresponding mechanisms have been identified. To create a better overview, all of these factors have been grouped together based on the conceptual framework shown in Figure 2.3. All mechanisms identified in the literature review are added to all factors they could contribute to. The resulting overview is shown in Table C.1.

Note that some factors and mechanisms have a lot of overlap. For instance, in relational governance, all three underlying factors have some sort of overlap. Besides, trust may be a product of successful business relationship and stakeholder management. Furthermore, mechanisms like decision-making structures and division of roles also overlap. Besides, many mechanisms are listed multiple times, as they contribute to multiple factors. Organizational maturity is a factor that does not have any mechanisms supporting it. That is, no mechanisms identified in the literature review. It correlates with interoperability, and depends on many existing factors. All of these concerns are a motivation to simplify this overview.

For this simplification, the third column of factors will be removed. Now that there is an overview of all these factors, there is no need to include them in a simplified model. They do also not occur in the conceptual framework. Furthermore, organizational maturity is removed, as it correlates with interoperability and is beyond the scope of this thesis to investigate. As QoS correlates with Service-Level Agreement (SLA), and SLA are a prominent mechanism, it is removed to. The same goes for ESB and brokers, as these are grouped under middleware. Division of roles, formal communications, and alignment processes are grouped under decision-making structures. Cloud Management Committee, Chief Cloud Officer, Cloud Relationship Centre, and Cloud Service Facilitation are grouped together as Cloud Office. Containerization is discarded as a mechanism as it is a completely technical solution and thus beyond the scope of this thesis. Finally, interoperability is also a factor under technical governance. Technical governance, as an element of business governance, influences coordination. Most mechanisms for interoperability are also relevant for technical level governance. Therefore, these are grouped together under technical governance.

Factors			**Mechanisms**
Inter-organizational governance	Contractual governance	Efficiency Risk	SLAs QoS OLA Decision-making structures Division of roles Cloud Management Committee Continuous audits
	Relational governance	Stakeholder management Trust Business relationship management	Alignment processes Formal communications Division of roles Chief Cloud Officer Cloud Relationship Centre
Business governance	Technical level	Data management Security Privacy IAM Infrastructure	SLA Alignment processes Division of roles IT Frameworks Middleware SOA ESB Broker
	Service level	Core competence management Top management support Asset utilization	SLA BLOs Decision-making structures Alignment processes Division of roles Chief Cloud Officer Cloud Management Committee Cloud Service Facilitation
Coordination	Interoperability	Legacy systems Loose coupling Data quality Network performance API management Re-usability	IT Frameworks Middleware SOA ESB Broker Standardization Containerization OLA Decision-making structures Alignment processes Chief Cloud Officer
	Organizational maturity		

Table C.1: Overview of all factors and corresponding mechanisms identified in the literature review

Factors		**Mechanisms**
Inter-organizational governance	Contractual governance	SLA OLA Audit program
	Relational governance	Decision-making structures Cloud Office
Business governance	Technical level (including interoperability)	IT Frameworks Middleware SOA Standardization OLA
	Service level	SLA BLOs Decision-making structures Cloud Office

Table C.2: Simplified overview of factors and corresponding mechanisms

A final note on the simplified overview is that some mechanisms influence many factors. For all factors, the most relevant mechanisms have been chosen. This means that some mechanisms also influence factors to which they are not listed. If in any doubt, refer back to the complete overview in Table C.1. The resulting simplified overview is shown in Table C.2.

Appendix D

Interviews

D.1 Interview questions cases

The questions found in Table D.1 are used in the interviews. The total interview time should be around one hour. Each main question should take around five minutes on average.

The questions are based on the themes deducted from the literature review, and should answer sub-questions 2, 3, and 4 as described in Section 1.4.

Interview questions 1, 2 and 3 are designed to understand how and why the organization is using multi-cloud. This will set the context for the rest of the interview.

Interview questions 4 and 5 are aimed at the challenges around multi-cloud systems. Along with the literature review, this should answer research sub-question 2. Challenges from question 5 that are already discussed in question 4 will be excluded from question 5. This list of challenges may be expanded in the future.

The literature review showed multiple factors and requirements for effective multi-cloud management. Different forms of governance and management play an essential role as factors in the multi-cloud context. They come with requirements like a certain degree of detail in contracts, or stimulated collaboration between cloud vendors.

Questions 6 through 9 focus on different types of governance, along with certain requirements for them. The final questions 10 through 13 are aimed at forms of management, also accompanied with several requirements.

Nr	Multi-cloud system and challenges
1	What is your perception of multi-cloud?
2	What kind of multi-cloud system does the organization use? (library-based or service-based, let interviewee describe this in own words)
3	What were the reasons for the organization to choose this system?
4	Which challenges does the organization encounter when managing this system?
5	Does the organization recognize issues with any of the following: interoperability, vendor lock-in, handling new releases, security and privacy?
Nr	**Governance**
6	What kind of contracts are used in the multi-cloud environment of the organization? *(contractual governance)* - How detailed are the contracts? - Who is dominant in the contracts? (organization or cloud provider) - Which KPIs are used? - (How) are SLAs arranged? - If yes, (how) are SLAs monitored?
7	Is there a mechanism in place to coordinate and/or stimulate collaboration between cloud providers? Is this needed, in your opinion? (e.g. OLAs, forced coopetition, this also depends on the kind of multi-cloud system. For this question, provide some background to the interviewee) *(contractual/inter-organizational governance)*
8	What happens when the system fails? *inter-organizational governance* - Who is accountable for failure? - Is there a team with members from both the organization and the cloud provider to handle this?
9	How are relations with and between cloud providers managed? *(relational governance)* - Is there a long-term connection or are cloud providers selected ad-hoc? - (How) is trust established in the multi-cloud environment?
Nr	**Forms of management**
10	To what degree is *technical management* (maintaining operability of the system) outsourced in the multi-cloud environment? - Who is responsible for the operability between the different cloud services/applications? (interoperability) - What happens when one of the cloud services/applications is updated?
11	How is the functionality of the system maintained? *(functional management)* - Who is responsible for this? - In case of failure in some part of the system, how can end users get help? - Is there a single helpdesk or point of contact in case of failure?
12	To what degree is management of the application/solution outsourced? *(application management)* - What data is shared with and between cloud providers? - To what degree are cloud services/applications coupled? - How are different APIs managed? - How is IAM (Identity and Access Management) arranged in the multi-cloud system?
13	How is change managed? (e.g. updates, innovations, legal, etc.)

Table D.1: Interview questions for the multiple-case study

D.2 Interview questions evaluation

The questions found in Table D.2 are used for the evaluation interviews. They are split into two parts: the findings of this thesis, labeled results, and the resulting framework. The findings are divided in technical aspects and governance and managerial aspects.

The first five questions focus on technical aspects of this research. Most have to do

with the integration platform, as this involves many factors and requirements, and mitigates most challenges. The answers to these questions should either confirm or refute that an integration platform is a good practice. Besides, it checks if the definition given in this thesis is correct. The technical questions also focus on alternatives for an integration platform. Furthermore, it investigates the intricacies about data management, and wether these are portrayed correctly in this thesis.

Questions 6 to 11 are focused on the governance aspects. These cover all levels of governance. The foundation of the framework is assessed on how correct it is, and what the expert's perception on this is. Furthermore, it looks at contracts, relationships, and roles in the multi-cloud context. The questions also check the relevance of existing IT frameworks, and the feasibility of theoretical models.

The final questions aim to evaluate the framework. This assesses the correctness of the framework and the usability in practical context. Besides, it aims to identify how accurate the framework is.

Nr	**Results**
Technical	
1	Is an integration platform always used for cloud integration?
2	Does an integration platform have the same functions as a traditional ESB?
3	Would an integration platform be useful for a service-based multi-cloud system?
4	Are there other tools to reduce the complexity in a multi-cloud environment?
5	What factors besides a master database, data mapping, security, and privacy are essential in data management?
Governance and management	
6	This thesis presents clear objectives, SLAs, and a division of roles as the foundation of effective governance. What is your perception on this?
7	Do you think that such relationships – build on a clear governance structure – result in trust?
8	Besides SLAs, there are also XLAs. Which one do you prefer and why?
9	How cost-effective is a mediator?
10	Do you think that forced coopetition is feasible or that it only has theoretical value?
11	Do you think that traditional IT frameworks are still relevant in the multi-cloud context?
Nr	**Framework**
12	To which degree do you agree with the order of steps in this framework?
13	How do you assess the usability of this framework?
14	What elements do you think that the framework is missing?

Table D.2: Interview questions for the evaluation