MSc Business informatics

Graduation thesis

A decision support framework for multi-cloud service composition

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Contents

Abstract

This thesis presents a multi-cloud framework that assists organizations in evaluating and selecting cloud service providers (CSPs) for their multi-cloud environments. The framework incorporates a decision model that utilizes the MoSCoW requirements prioritization technique and Weighted Sum Model for computational purposes. This enables organizations to effectively prioritize requirements based on their relative importance in facilitating the achievement of successful multi-cloud adoption. The framework allows organizations to identify and prioritize the most suitable CSPs by leveraging multiple features and assigning higher priority to critical requirements. A systematic literature review was conducted to establish a comprehensive understanding of the multi-cloud domain, encompassing adoption, selection, migration techniques, and relevant features and providers, which were further validated through consultations with domain experts. Through an iterative process, the decision model was developed and validated using three case studies, demonstrating its effectiveness in assisting organizations in selecting a suitable multi-cloud environment and evaluating the compatibility of their existing setups. While the decision model provides a best-match suggestion, organizations should conduct further analysis and address specific contractual issues with the selected CSPs to ensure a proper fit. Consequently, the decision model serves as an initial guide, providing a shortlist of CSPs that warrant closer examination by the organization. Additionally, the collection of multi-cloud environment features, derived from domain expert insights, systematic literature review, and document analysis, contributes to a comprehensive overview of the multi-cloud domain, offering valuable insights for addressing future challenges.

Chapter 1

Acknowledgements

We would like to express our sincere gratitude to the twelve domain experts who enthusiastically participated in the interview sessions and provided invaluable insights that greatly enriched our research. Their active involvement and valuable contributions are gratefully acknowledged and greatly appreciated. We extend our profound appreciation to the organisations willing to actively participate as case study partners in our research. Their collaboration and involvement played a crucial role in assessing the validity of our decision model. We are grateful for their contributions, which significantly advanced our study. Lastly, we thank Avanade for providing the opportunity to pursue an internship focused on this topic and for their insightful perspectives and assistance throughout our research.

Chapter 2

Introduction

Currently, organizations are actively involved in digital transformation initiatives and adopting technologies to improve their operations and services. The objective of this transformation is to ensure survival and achieve profitable business growth during the fourth industrial revolution, which encompasses advancements such as the Internet of Things, big data analytics, autonomous vehicles, 3D printing, artificial intelligence, robots and drones, social media solutions, and cloud computing (Yoo & Kim, 2018).

Since the introduction of cloud computing services in 2006, their adoption has experienced significant growth. For example, in South Korea, IT spending was projected to increase from $67 billion in 2015 to $162 billion in 2020, indicating a remarkable surge of almost 250% (Yoo & Kim, 2018). Cloud computing has gained tremendous popularity.

This thesis explores the cloud computing domain and aims to develop a decision model for multi-cloud service composition. In this chapter, we will discuss the advantages of cloud computing.

The impact of cloud computing on an organization is largely dependent on the deployment and delivery models chosen. The cloud computing landscape consists primarily of three main types of delivery models (Abdel-Basset, Mohamed, & Chang, 2018):

- Software as a Service (SaaS): An extension of service delivery that allows access to complete applications.
- Platform as a Service (PaaS): Offers a programming environment that facilitates the development and deployment of software applications.
- Infrastructure as a Service (IaaS): Provides the necessary infrastructure to host, operate, and manage storage, offering physical computing power.

Computing clouds are commonly categorized into five distinct deployment models. By categorizing computing clouds into these deployment models, organizations can make informed decisions regarding the most suitable cloud environment for their specific needs and objectives:

- Public Cloud: Public cloud services are provided by third-party vendors and are available to the general public over the Internet. Users share computing resources, such as servers and storage, hosted in the provider's data centers. Examples of public cloud providers include Amazon Web Services (AWS), Microsoft Azure, and Google Cloud Platform (GCP) (S. Zhang, Zhang, Chen, & Huo, 2010).
- Private Cloud: A single organization exclusively uses a private cloud infrastructure. It can be managed internally by the organization or by a third-party service provider. The infrastructure and services are dedicated to the organization, offering increased control, privacy, and security (Rittinghouse & Ransome, 2016).
- Hybrid Cloud: Hybrid cloud combines both public and private cloud infrastructure, allowing organizations to leverage the benefits of both. It enables seamless transfer of data and applications between private and public cloud environments, providing flexibility and scalability (Armbrust et al., 2010).
- Community Cloud: Community cloud is shared by organizations with similar requirements, such as government agencies, research institutions, or industry consortia. The cloud infrastructure is customized to meet the specific needs of the community members (Buyya, Ranjan, & Calheiros, 2010).
- Multi-cloud: Multi-cloud refers to using multiple cloud computing services from different providers. It involves the distribution of workloads across various cloud environments, allowing organizations to leverage different features, cost structures, and geographic locations (S. Zhang et al., 2010).

The adoption of cloud computing has witnessed a significant surge driven by the demand for an adaptable, flexible, and scalable IT infrastructure that allows for a dynamic, agile work culture. Cloud computing offers several advantages, including cost-effectiveness, dynamic scalability, enhanced availability, quality of service (QoS), pay-per-use pricing models, and user-friendliness. These features collectively position cloud computing as a promising business opportunity (Shuaib, Samad, Alam, & Siddiqui, 2019).

Organizations can leverage cloud computing to eliminate the need to invest in, maintain, and deploy their IT infrastructure and applications. This mitigates administrative overheads and reduces technical complexities (ur Rehman, Hussain, & Hussain, 2011). The cloud computing paradigm enables businesses to streamline their operations and focus on core competencies while relying on an external service provider for IT infrastructure and management.

Despite the many advantages of cloud computing, the adoption of cloud services faces various challenges and barriers. One of the main concerns are the issue of security and data privacy (Phaphoom, Wang, Samuel, Helmer, & Abrahamsson, 2015). This apprehension arises from the uncertainty surrounding achieving comprehensive security across different levels, including network, application, and data security (Avram, 2014).

In addition to security concerns, other significant challenges include ensuring reliability and performance. Applications hosted on the cloud must exhibit robust reliability and uninterrupted availability to support continuous operations, as any instances of downtime can result in substantial costs. Furthermore, the integration challenges stemming from the complexity of existing IT infrastructures pose additional obstacles. As organizations progressively standardize their processes, establishing integrated connections and infrastructures, the integration of cloud solutions can become intricate. However, it is essential to acknowledge that cloud services have the potential to address these complexities and serve as a solution. The interoperability between existing systems and the cloud environment influences the successful adoption of cloud services, which can facilitate and hinder the adoption process (Avram, 2014).

Although these barriers may discourage cloud adoption, the value of cloud computing is increasingly apparent through the success stories observed in various industries (Phaphoom et al., 2015).

Organizations are faced with selecting from a range of cloud service providers (CSPs) when adopting cloud services. The proliferation of CSPs has seen significant growth, and prominent IT companies such as Amazon and Microsoft compete to offer customers the most suitable cloud solutions (Youssef, 2020).

Cloud adoption initiates a customer migration process that encompasses three possible migration scenarios: migrating legacy systems to the cloud, transferring data and applications between different cloud providers, or adopting cloud services without any prior on-premises systems. Each type of migration entails distinct technical requirements and concerns, including data management, security, legal considerations, interoperability, high latency, and the risk of vendor lock-in (Hong, Dreibholz, Schenkel, & Hu, 2019).

To mitigate these concerns, organizations often employ a multi-cloud strategy, which involves the deployment of multiple clouds to create a multi-cloud landscape. A multi-cloud landscape facilitates cloud interoperability and offers several benefits, such as improved flexibility, enhanced reliability, and increased options for resource allocation and load balancing (Toosi, Calheiros, & Buyya, 2014). Furthermore, multi-cloud deployments provide the following benefits:

1. Greater Scalability: By leveraging the combined services of multiple cloud providers, organizations can achieve greater scalability, enabling them to meet varying demands and accommodate resource-intensive workloads more effectively.

2. Vendor Lock-In Prevention: Cloud interoperability is crucial in preventing vendor lock-in, where a customer becomes excessively dependent on a particular vendor's products or services. This dependency restricts the customer's ability to switch to an alternative vendor without incurring significant costs and technical complexities.

3. Improved Availability and Disaster Recovery: The deployment of multiple clouds enhances availability and facilitates improved disaster recovery capabilities. By strategically distributing cloud applications across multiple cloud deployments, organizations

can achieve higher levels of availability, ensuring uninterrupted service delivery, and maintaining desired service quality.

4. Low-Latency Access: When users are geographically dispersed, maintaining a fast response time is challenging. Utilizing multiple clouds is the only way to achieve low-latency access.

5. Load Distribution: A multi-cloud landscape facilitates load distribution,allowing organizations to distribute peaks in demand across multiple cloud providers. Research has shown that interconnected clouds can significantly reduce costs and energy consumption while effectively managing workload fluctuations and resource utilization.

The various advantages offered by multiple CSPs and the absence of a single CSP capable of meeting all organizational requirements have led to the emergence of a multi-cloud landscape as a potentially optimal solution for organizations (X. Zhang, Li, & Zhu, 2015). However, the existence of numerous CSPs and the limited transparency of their offerings pose significant challenges in identifying the most suitable providers for organizations (Saha, Panda, & Panigrahi, 2021).

Organizations recognize that leveraging a combination of multiple CSPs allows them to capitalize on the strengths and capabilities of different providers, resulting in enhanced flexibility, scalability, and resource availability.

2.1 Problem Statement

As mentioned in the introduction, the adoption of cloud technology is widespread and offers numerous advantages. However, due to the presence of multiple CSPs, choosing the most suitable provider becomes a challenging task (Saha et al., 2021). Customers must have adequate knowledge to choose a CSP that meets their requirements and ensures optimal future performance while complying with legal, policy, and regulatory frameworks (Youssef, 2020).

The existing body of cloud service selection (CSS) research encompasses various approaches and methods. Among these, the primary techniques explored for selecting and ranking single CSPs include multi-criteria decision-making (MCDM) and multi-criteria optimization techniques (Sun, Dong, Hussain, Hussain, & Chang, 2014). These methods primarily focus on evaluating criteria and user preferences (Nawaz et al., 2018). However, it is essential to note that there are still gaps in this research domain (Sun et al., 2014):

1. The transparency of the CSP marketplace is limited, with a lack of comprehensive information regarding QoS, preventing an effective comparison between different providers.

2. A standardized and universally accepted method for comparing and evaluating various cloud providers is absent.

3. There is a lack of updated repositories containing comprehensive information on CSPs.

4. Existing research primarily focuses on single-tenant service selection, while the issue of multi-tenant service selection remains unresolved. Multi-tenancy refers to using a single cloud provider by multiple users with distinct requirements, making it impossible for a single provider to fulfill all user needs.

5. User preferences play a vital role in the ranking of services. However, there is a need for a quantitative approach to capture subjective opinions and improve the objectivity of service selection.

6. The selection of appropriate criteria is crucial to making rational decisions. However, the current literature assumes that the attributes of the service are independent of each other, neglecting the interdependencies and relationships between criteria such as compensation and dominance, which requires further exploration.

7. The comparison of CSPs during the selection process is challenging due to qualitative parameters and numerous nonfunctional properties, including user experiences and subjective opinions. An efficient approach to address this uncertainty needs to be developed.

8. The selection process is typically treated as a static task with a "once-and-for-all" problem solving approach. However, viewing the process as dynamic is crucial, acknowledging that changes may occur and long-term considerations should be taken into account.

This research was motivated by several identified gaps in the field, specifically focusing on the selection of multi-cloud services. Existing literature has only marginally addressed the topic of multi-cloud service selection and has overlooked the consideration of requirements. Investigating this particular gap holds significant relevance due to the manifold benefits associated with cloud interoperability, as discussed in the introduction. For organizations, the ability to identify suitable providers capable of fulfilling all their requirements yields substantial advantages. However, the complex and non-transparent nature of the CSP market poses significant challenges in determining the optimal service combination (Dahan, Binsaeedan, Altaf, Al-Asaly, & Hassan, 2021).

In conclusion, the research gaps in the realm of CSS and the advantages associated with cloud interoperability provided the foundation for the present study.

2.2 Research Questions

Given the problem statement, this research focuses on answering the following question:

- **MRQ**: *How to build a decision model on adoption and migration challenges in multi-cloud?*

To support the main question, the following supporting questions have been formulated:

- **RQ1**: *What existing methods are available in the literature for cloud service selection in single and multi-cloud environments?*

- **RQ2**: *Which evaluation methods can be considered to assess the solutions derived from the framework?*

  To answer the above questions, a systematic literature review has been conducted to understand the existing knowledge in the field, which will be elaborated in Chapter 4. The research questions aim to gain domain knowledge of the state-of-the-art and optimize our approach.

- **RQ3**: *Which method is optimal for creating the decision support framework?*

- **RQ4**: *What are the essential features of the decision support framework?*

  These two research questions will also be answered through a systematic literature review and validated and prioritized through expert interviews. The main objective is to identify the necessary features that the framework should incorporate.

- **RQ5**: *How can a framework be designed for modeling multi-cloud provider composition?*

  Using design science methodology, the MCDM methodology, and insights from domain experts, the research aims to develop a comprehensive understanding of how to design the framework.

- **RQ6**: *How can the proposed decision support framework be evaluated?*

  The answer to this question will be provided through the implementation of three case studies conducted across multiple industries.

2.3 Contributions

As outlined in the introduction, there are notable research gaps in the field of cloud service selection (CSS). This study aims to address these gaps by focusing on multi-cloud service selection and identifying the optimal evaluation criteria while providing comprehensive data on CSPs within the scope of this research.

The selection of suitable CSPs presents a significant challenge for organizations due to the lack of transparency in available information. There is a need to systematically gather, organize, store, and make accessible the knowledge related to CSPs for timely utilization. Therefore, there is a demand for a decision support system that assists organizations in selecting suitable CSPs based on their specific requirements.

A key contribution of this research will be the development of a feasible combination mapping, as depicted in Figure 2.3. The combination of CSPs based on specific requirements has not been extensively explored in the existing literature on multi-cloud.

This research comprises two primary artifacts. The first artifact focuses on guiding organizations in constructing their knowledge base, which includes the current CSPs and the corresponding requirements they fulfill. This knowledge base will enable organizations to gain valuable insights into CSPs and facilitate the selection of the most suitable providers according to their specific requirements. The second artifact encompasses the foundational elements of the proposed decision support framework.

The overarching objective of this study is to assist organizations in streamlining their CSS process, with a specific emphasis on multi-cloud service composition.

2.4 The MCDM Framework Development Process

Tools and techniques rooted in Multi-Criteria Decision Making (MCDM) encompass mathematical decision models that aggregate criteria, perspectives, or features (Floudas & Pardalos, 2008). In MCDM, support is a fundamental concept that implies decision models are not developed through a passive process, where decision-makers play a passive role (Dvořák, Pergl, & Kroha, 2018). Instead, an iterative and systematic process is used to analyze decision makers' priorities, as in this research, with the aim of representing them accurately and consistently within an appropriate decision model. This iterative and interactive modeling approach forms the foundational principle of decision support in MCDM, distinguishing it from statistical and optimization-based decision-making approaches (Gil-Aluja, 2013). In this study, we adopted a similar approach for our research methodology.

The process of theory development is an incremental and continuous cycle (Simon, 1955), which requires precise design decisions. It involves the stages of description, explanation, and validation of the theory (Cooper & Emory, 1995). The description stage takes precedence, and in each cycle of the development process, new constructs and relationships are meticulously defined or revised to maintain consistency among the components of the theory. The **description** stage aims to obtain a comprehensive understanding of the constructs and provide a well-documented characterization of the MCDM framework, serving as the basis for building and testing the framework. During this stage, an initial set of constructs and relationships is proposed (Farshidi, 2020). Hospers (1956) presents three common interpretations of the **explanation** stage in the development process: (1) stating the scope of the framework, (2) demonstrating how the framework relates to familiar phenomena, and (3) aligning the framework with established laws or principles. In other words, the explanation stage translates interpreted observations and ideas into new constructs of the framework. The **validation** stage verifies the identified constructs from the earlier stages. It involves predicting outcomes in either the explanation or the description stage. This stage requires making conceptual design decisions for the empirical evaluation and validation of the framework (Farshidi, 2020).

Figure 2.1, based on (Farshidi, 2020), illustrates how the MCDM framework, grounded in MCDM theory, is instantiated to build a decision model that supports organizations in their decision-making process for CSP selection.

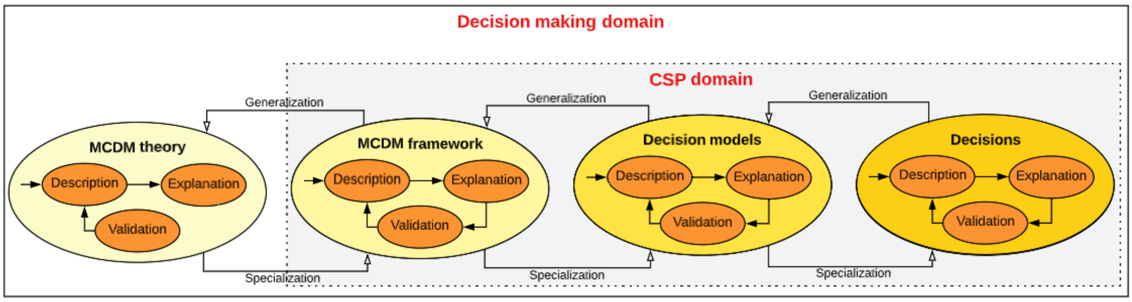


Figure 2.1: The MCDM framework, derived from MCDM theory, is employed to create decision models that offer support to organisations for CSP selection (Farshidi, 2020).

2.5 Selection process

Figure 2.2 presents a meta-model that serves as a decision-making framework within our study. This model draws inspiration from the work of (Farshidi, Jansen, & van der Werf, 2020). The meta-model provides a holistic representation of the interrelationships between CSP features, requirements, and the underlying architecture. It establishes a foundation for discussing the specific ways in which features influence the desired cloud or multi-cloud solution and describes their impact on the decision-making process of organizational decision-makers.

Organizations seeking to choose a cloud provider must adhere to a well-defined **selection rationale**. The selection rationale involves a methodical process of reasoning and decision-making, where specific criteria and objectives are employed to compare and choose from various alternatives (Saaty, 2008). This rationale justifies the **cloud selection** process. Opting for an appropriate cloud provider involves the utilization of a **decision model** that assesses various CSPs, taking into account their distinctive features and, in some cases, combining multiple CSPs to encompass a broader array of features. The chosen cloud selection

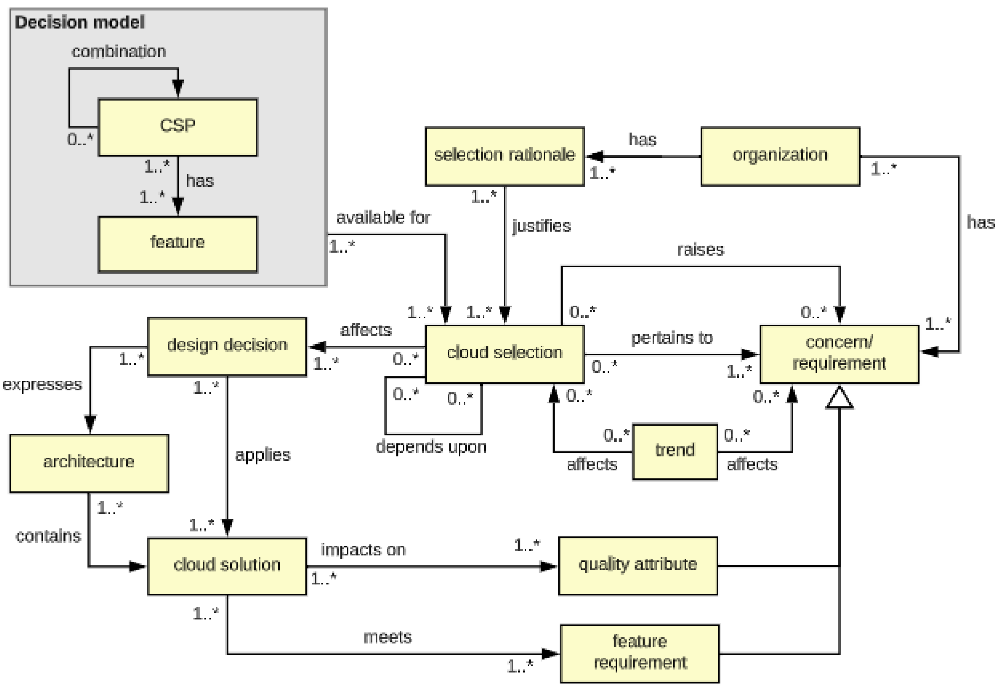


Figure 2.2: Selection model of our framework

significantly influences the **design decision**, which pertains to the choices made during the creation or development of a product, system, or solution. These design decisions profoundly impact the functionality, maintainability, and adaptability of the organizational software environment (Boehm, 1988). The design decision inherently expresses the architecture where the chosen cloud selection is integrated, and the cloud solution is applied.

Cloud computing fundamentally reshapes the design of applications and system architecture, introducing new paradigms and considerations for designing and implementing systems (Armbrust et al., 2010). According to NIST, a **cloud solution** is defined as "A cloud model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction" (Mell, Grance, et al., 2011). The cloud solution significantly impacts **quality attributes** and fulfills **feature requirements**, encompassing features identified in the literature shown in Table A.2. Both quality attributes and feature requirements encapsulate an organization's **requirements and concerns**. The cloud selection should align with these requirements, which are subject to potential alterations driven by **trends** and future directions in cloud computing. Current trends indicate shifts in cloud infrastructure, such as exploring multi-provider infrastructures and the advantages of decentralized computing beyond traditional data centers (Varghese & Buyya, 2018). These trends can create diverse requirements within organizations.

2.6 Framework

A conceptual model was developed to visually represent the framework, as illustrated in Figure 2.3. The model was devised to enhance the comprehension of the research-derived framework. The framework is structured into five distinct modules: Knowledge Acquisition, Decision Model, Score Calculation, Decision, and Organization. Each module fulfills specific functions and collectively contributes to the decision-making process for multi-cloud adoption.

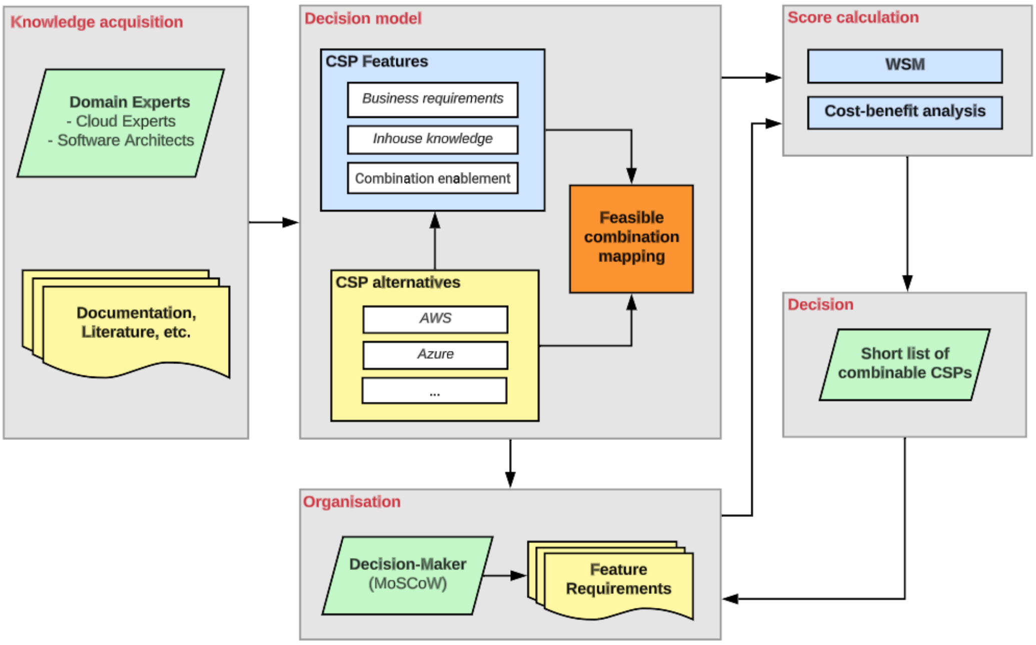


Figure 2.3: Framework for multi-cloud service selection

- The **knowledge acquisition** module plays a crucial role as a repository for collecting domain knowledge and fundamental components of the framework. It involves conducting interviews with **domain experts**, such as cloud experts and software architects, to validate and gather information on the essential features required for selecting CSPs. Additionally, **documentation and literature sources**, including systematic literature research and analyses of CSP documents, are used to collect pertinent data and information about CSPs.

- The **decision model** comprises three key elements. First, the features **of the CSP** are defined as the characteristics on which the CSPs can be compared and selected. These features are categorized into three main groups: business requirements, in-house knowledge, and combination enablement, as elaborated in Chapter 6. Secondly, the **CSP alternatives** are specified, representing the set of CSPs that will be included in the decision model. Lastly, the **feasible combination mapping** explores the viable combinations of CSPs and maps their features to the corresponding providers, providing information on potential provider compositions that align with an organization's requirements. This process facilitates the calculation of the optimal option considering an organization's specific needs.

- The **score calculation** module is responsible for determining the most feasible cloud or multi-cloud solutions. It employs a **cost-benefit analysis** approach, systematically cataloging the impacts as benefits (pros) and costs (cons) by assigning appropriate weights (Boardman, Greenberg, Vining, & Weimer, 2017). The **Weighted Sum Model** (WSM) is utilized for calculating the overall scores.

- The **decision** is made by analyzing the scores, resulting in a **shortlist of combinable CSPs**. This shortlist provides the organization with viable options to consider for further decision-making.
- The **organization** has a designated **decision maker** who possesses a list of **feature requirements**. The decision maker prioritizes these requirements using the MoSCoW prioritization method, taking into account the features defined in the framework.

2.7 Thesis layout

This research commences with an introductory section that encompasses the research problem, research questions, and contributions. Within this section, the background and rationale for conducting the research are discussed. Subsequently, in Chapter 3, the research approach is elaborated. This chapter explains the research questions, expert interviews, literature study, design science, and case studies undertaken in the research process.

Chapter 4 is dedicated to the literature review, providing an account of the methodology employed to conduct the review and presenting the key findings derived from the literature. Following the literature review, Chapter 5 presents the results of the expert interviews conducted. By using the insights gathered from both the literature and interviews, Chapter 6 presents and explains the fundamentals of the framework employed in the study.

The evaluation of the framework is carried out in Chapter 7, wherein three case studies are comprehensively explicated. These case studies serve to assess the validity and applicability of the framework.

The findings and insights derived from the case study, interviews, lessons learned, threats of validity, and identified limitations are comprehensively discussed in Chapter 8, providing a comprehensive analysis of the topic at hand. Lastly, Chapter 9 presents the concluding remarks and outlines avenues for future research in this domain.

Chapter 3

Research Approach

This chapter outlines the methodology that will be employed in conducting this research and describes the approach taken to address the research questions. The research methods will be extensively discussed, highlighting the specific techniques and procedures used.

3.1 Research Methods

To address the research questions delineated in Section 2.2, a wide range of research methods will be used. Four distinct methods have been selected for this research, namely literature research, expert interviews, case study analysis, and design science. Each of these methods will be described in detail and associated with specific research questions, as illustrated in Table 3.1. The intersection between the research questions and the corresponding methods will be marked with an "X" to indicate the methods utilized to answer each research question.

Research questions		Research methods			
		Literature study	Expert interview	Case Study	Design Science
MRQ	How to build a decision model on adoption and migration challenges in multi-cloud?	X	X	X	X
RQ1	What existing methods are available in the literature for cloud service selection in single and multi-cloud environments?	X			
RQ2	Which evaluation methods can be considered to assess the solutions derived from the framework?	X	X		
RQ3	Which method is optimal for creating the decision support framework?	X	X		
RQ4	What are the essential features of the decision support framework?	X			
RQ5	How can a framework be designed for modeling multi-cloud provider composition?		X		X
RQ6	How can the proposed decision support framework be evaluated?			X	

Figure 3.1: Research methods used

3.1.1 Literature Study

Acquiring a comprehensive understanding of the cloud computing domain requires detailed research efforts. We conducted a semi-systematic literature review (SLR) to delve deeply into cloud computing. The initial phase involved identifying the prevailing trends and analyzing the existing body of knowledge to identify potential research gaps. This served as a crucial foundation for our research, aiming to contribute to the scientific community by addressing these gaps. We meticulously compiled various features and techniques for cloud service selection, adoption, and migration throughout the SLR process. This data was instrumental in facilitating informed modeling decisions.

To conduct our literature review, we follow the well-established protocol proposed by Kitchenham (Kitchenham, 2004). This protocol entails ten distinct phases, and the overall SLR process is visually depicted in Figure 4.2. Each phase will be explained below.

- **Problem formulation** constitutes a critical initial step in the research process. This phase involves defining the research area and formulating a concise problem statement that delineates the scope of the study. A detailed elaboration of the problem formulation is presented in Section 2.1.

- The **initial hypotheses** phase involves transforming the problem formulation into a clear set of hypotheses. This phase precedes the initiation of the SLR and consists of formulating research questions and defining hypotheses. The research questions are presented in Section 2.2.

- **Initial data collection** entails collecting an initial set of relevant papers. This collection process was accomplished by manually searching for papers based on the defined initial hypotheses.

- Following the initial data collection, the **query string definition** phase ensues. This phase involves creating a query string comprising key terms and abstracts from the collected papers. The query string was designed to retrieve a comprehensive selection of relevant papers.

- The subsequent phase is the **digital library exploration**, where the query string was inputted into various digital libraries. Table 4.1 provides an overview of the libraries utilized and the corresponding number of articles generated based on the query string. The papers retrieved from the digital libraries are then exported to CSV or BibTeX files and imported into a spreadsheet for further analysis.

- A **relevancy evaluation** was conducted to assess the papers retrieved from the digital libraries. Each paper was assigned an ordinal relevancy rating (none, low, medium, or high) based on its alignment with the research scope. Additionally, relevant information such as title, URL, authors, abstract, keywords, year of publication, number of citations, and publication venue, including its ranking, were collected. This process results in a pool of publications.

- Following the relevancy evaluation, the **publication pruning process** was initiated. In this phase, papers were selectively included or excluded based on predetermined criteria. Inclusion and exclusion decisions are guided by relevancy, venue ranking, year of publication, and number of citations.

- The pool of papers that have successfully passed the relevancy evaluation and publication pruning process undergoes a **quality assessment process**. These papers are subject to a more comprehensive review, focusing on various aspects, including research methodology, data collection methods, evaluation techniques, and content-related elements such as problem statements, research questions, research challenges, clarity of findings, and real-world use cases. These papers are incorporated into our knowledge base based on their relevancy and quality.

- **Data extraction and synthesis** are performed on the papers included in our knowledge base. This phase involves extracting relevant data about CSS techniques, adoption strategies, and migration approaches. Additionally, various selection, adoption, and migration features discussed in the literature are identified and collected. This synthesized data provides insights into the state-of-the-art approaches in CSS and other relevant domains. During the synthesis process, less popular models and infrequently mentioned features are filtered out, and similar features with different terminologies are consolidated.

- Finally, **snowballing** serves as the concluding phase, wherein additional papers are discovered by leveraging our knowledge base and examining the references of the included papers.

3.1.2 Design Science

Design science, as proposed by Hevner (Hevner & Chatterjee, 2010), serves as a framework for introducing novel artifacts and processes to enhance existing environments. This methodology is particularly relevant in the field of information systems research. The design science methodology comprises three interrelated cycles: The Relevance Cycle, Rigor Cycle, and Design Cycle, as depicted in Figure 3.2.

The **Relevance Cycle** places significant emphasis on the relevance of the research within the application context. It involves identifying requirements and defining acceptance criteria for evaluating the study's outcomes. The primary objective of this cycle is to elucidate how the design artifact enhances the environment and establish measurable means to assess its impact.

The **Rigor Cycle** underscores the necessity of creating a knowledge base encompassing scientific theories and engineering methods. This knowledge base contains theoretical principles, practical experiences, domain expertise, and application practices, including existing artifacts and processes. Through this cycle, researchers establish a comprehensive understanding of the state-of-the-art in the research domain.

The **Design Cycle** represents the core of the research process, where the principal investigator's ideas are materialized. This cycle involves iterative activities encompassing the construction and evaluation of the artifact. Valuable feedback is obtained during the evaluation phase to refine and improve the design. Maintaining a delicate equilibrium between construction and assessment is pivotal to ensuring optimal development of the artifact.

All three cycles collaboratively contribute to designing and refining an artifact that will effectively enhance the research environment. Figure 3.2 visually illustrates the Design Science model and showcases the interconnections of the various life cycles involved in this methodology.

3.1.3 Expert Interview

In addition to the SLR, this study incorporates twelve semi-structured interviews with experts in the field of cloud computing to obtain further insights about the domain. Following the

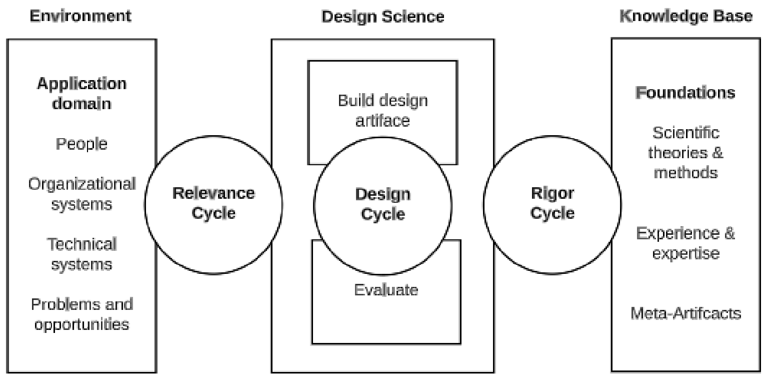


Figure 3.2: Design Science methodology (Hevner & Chatterjee, 2010).

establishment of a knowledge base through the SLR, the gathered data is evaluated and prioritized to ensure the relevance of the identified features.

The interviews were conducted in a semi-structured manner, involving predefined questions that guided the discussion. This approach allowed for open communication, enabling the exploration of new ideas and suggestions about the research topic. Each interview was approximately 60 minutes long, and all sessions were conducted online with the explicit consent of the participating experts. The interviews were recorded to ensure accurate data collection, and the collected information is presented in a Mendeley data (Bieger, 2023).

The interview participants were selected based on their expertise and experience, as indicated on their LinkedIn profiles. The selection criteria included the number of years of experience, job title, and educational background. Specifically, the participants were required to have more than ten years of experience in the IT domain with familiarity with multi-cloud, and their academic qualifications should be at least equivalent to secondary vocational education or higher. Moreover, interviews were conducted with experts from six organizations actively engaged in the IT domain. This selection strategy aimed to capture various perspectives and insights from industry professionals.

3.1.4 Case Study

This study will employ a multi-case study approach, following the methodology proposed by Stake (Stake, 2013), whereby multiple similar cases will be examined individually to derive comprehensive conclusions. This study will select three organizations as individual cases to evaluate and validate the proposed framework using real-world requirements.

The research will involve conducting three case studies, each utilizing a multi-cloud environment. The selected organizations will represent different industries, ensuring a diverse representation of sectors to assess the model's applicability and validity across multiple industries. This approach allows for a comprehensive evaluation of the framework's effectiveness and suitability in different organizational contexts. All sessions were conducted online with the explicit consent of the participating case studies. Recordings of the interviews were made to ensure accurate data collection, and the collected information is presented in a table shown in the Mendeley data (Bieger, 2023).

Chapter 4

Literature Review

This chapter presents the outcomes derived from the systematic literature review (SLR) and document analyses conducted as part of this research. The primary objective of the SLR was to acquire valuable insights into the cloud computing domain and address the specific research questions outlined in Table 3.1. The collected data serves as a foundational resource for defining the key features of the decision framework, establishing a comprehensive list of CSPs, and identifying the various techniques employed in investigating cloud service selection, adoption, and migration. Document analyses were also conducted to supplement the limited literature on multi-cloud compatibility.

We can identify the most suitable features and techniques to support our research objectives by thoroughly analyzing this data. This chapter begins by providing a detailed account of the SLR process, including the methodology employed, the decision-making processes undertaken, and the findings obtained. For a comprehensive overview of the collected data, please refer to the Mendeley data repository (Bieger, 2023). Subsequently, our research is positioned within the literature in the related work section. Finally, the chapter concludes with an overview of the document analyses conducted to augment the research findings.

4.1 Data Sources and Search Strategy

This section will discuss the data sources and search strategy employed in the SLR. The papers included in the SLR were identified through two distinct search methods: the initial hypothesis and automatic search.

The initial hypothesis involved a manual search on Google Scholar, which allowed us to gain domain knowledge and identify relevant papers about our subject matter. These papers provided valuable keywords that could be utilized to formulate a more comprehensive search term. Subsequently, after sufficient papers were collected, their keywords were generalized and employed in the automatic search phase.

We defined a search query for the automatic search to retrieve results from reputable scientific search engines. The selected digital libraries used in the automated search are listed in Table 4.1. These libraries were chosen due to their established reputation for hosting high-quality research papers. Notably, Google Scholar was not included in the automatic search process due to the abundance of grey literature and substantial overlap with the other selected digital libraries.

Source	Acronym	Amount of papers
IEEE Xplore Digital Library	IEEE Xplore	686
ScienceDirect	-	192
ACM Digital Library	ACM DL	201
Springer Publishing	Springer	193

Figure 4.1: Selected digital libraries

4.2 Search process

The search process started with formulating an initial hypothesis, whereby a collection of papers was assembled to address our research questions. This initial hypothesis led to the development of specific queries designed to guide our investigation. The queries generated as a result were as follows:

For the preliminary investigation, we executed nine distinct queries to explore various facets of cloud computing. Initially, the queries were designed to encompass cloud adoption and migration challenges, aiming to gain insights into the obstacles encountered in cloud computing. Additionally, we examined cloud provider comparisons to discern variations between different cloud providers, thereby ascertaining the relevance of multi-cloud approaches. Furthermore, we conducted a search focused on cloud service providers and the associated selection criteria employed in decision-making processes.

Moreover, we also targeted the financial industry in four search terms to identify pertinent trends and barriers relevant to cloud adoption within this sector. In parallel, we endeavored to locate scholarly papers about multi-cloud environments. Nevertheless, the initial search yielded limited outcomes in this domain, unveiling a discernible gap in the existing literature. The search terms utilized in this study can be found in the Mendeley Data repository (Bieger, 2023).

The search terms for the initial hypotheses resulted in a set of 98 relevant papers. The keywords were extracted to generate a search term used in the automatic search phase. The search process and the number of collected papers are shown in Figure 4.2.

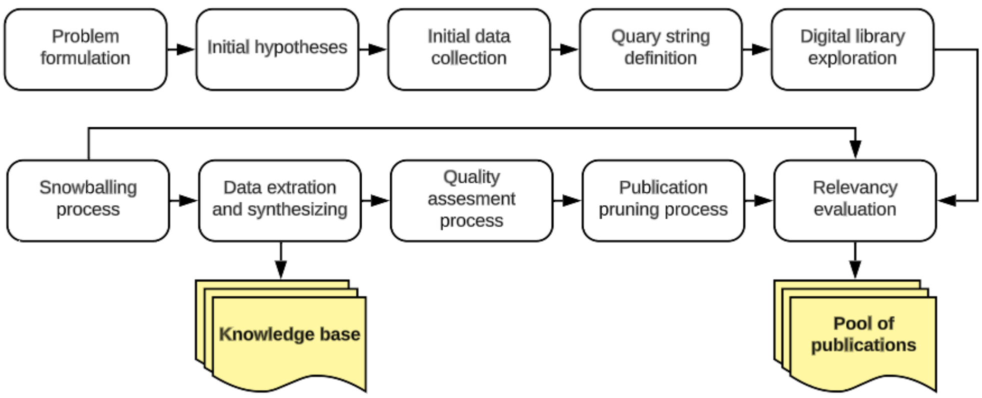


Figure 4.2: SLR search process

The search term generated was used to gather all the relevant papers from the libraries mentioned in Table 4.1. Entering the search term into these libraries provided CSV or Bibtex formatted files, allowing us to combine them into our spreadsheet. After removing duplicates and faulty values, the automatic research resulted in 1141 papers. The complete set of 1238 papers was considered during the SLR. We filtered valuable papers during the publication pruning and quality assessment process. After this analysis, 175 articles remained. Figure 4.3 shows the distribution of papers by publication year. The process will be elaborated below.

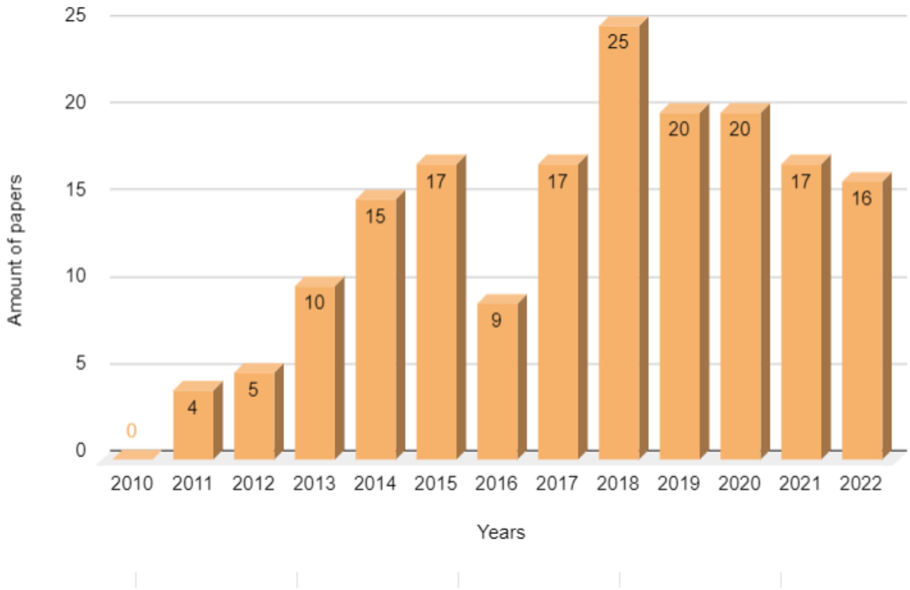


Figure 4.3: Distribution of papers by year

4.3 Publication pruning process

Following the initial search process, the relevancy of each identified paper was evaluated with respect to our research objectives. A ranking system utilizing four ordinal values (none, low, medium, and high) was employed to assess the papers, with "none" denoting irrelevance and "high" indicating strong relevance to our research. The determination of relevancy involved carefully examining the abstracts, keywords, and conducting a screening of the papers.

During the publication pruning process, the papers were classified as either relevant or irrelevant based on the satisfaction of inclusion and exclusion criteria. To be included in the SLR, a paper had to meet specific criteria, including being written in English, accessible as open access, falling within the scope of our study, meeting publication year requirements, and possessing sufficient quality.

A score was calculated for each paper based on the criteria mentioned above, with the score increasing if the paper exhibited high quality or was published more recently. The publications that fulfilled all the requirements underwent a comprehensive quality assessment, resulting in a final set of 236 papers for further analysis.

4.4 Quality assessment process

Preceding the data extraction and synthesis stages, a critical step in the research process involves conducting a thorough quality assessment of the selected papers. This assessment is carried out after the publication pruning process to facilitate a more comprehensive and in-depth review, aligning with established procedures outlined by Kitchenham (Kitchenham, 2004).

The paper quality was evaluated using specific criteria, as illustrated in Table 4.4. Each paper was reviewed against these criteria, with responses recorded as either "yes" or "no". Subsequently, a final score was calculated based on the assessment outcomes, resulting in 175 papers passing the quality assessment stage. These 175 papers were then incorporated into our knowledge base for further analysis and synthesis.

Quality assessment	Definition
Clear problem statement	The problem statement, if provided, underwent a thorough review and examination.
Research question	The research questions, if available, were identified and documented for further investigation.
Clear research challenges	The paper should explicitly address the research challenges encountered in the study.
A clear statement of findings	The paper should provide well-defined results and findings.
Real-world use cases	Examined whether the study incorporated a real-world case

Figure 4.4: Quality assessment process criteria (Kitchenham, 2004)

4.5 Data extraction and synthesizing process

The 175 papers that successfully passed the publication pruning and quality assessment process were subjected to data extraction. To enhance our understanding of the domain and obtain valuable insights, information related to various aspects such as features, techniques, and CSPs was extracted. Specifically, the extraction of features and techniques focused on cloud selection, adoption, and migration to identify the most appropriate ones to support decision-making processes. Similarly, the extraction of CSPs aimed to identify the most significant providers in the domain.

All reviewed papers were categorized based on subject, application, and domain to establish a more structured knowledge base for future reference. This categorization enables better organization and facilitates easier access to relevant information. The collected data will be analyzed to determine the importance of different elements, which will inform the development of features for our decision framework.

Synthesis was also carried out during the data extraction process to ensure validity and accuracy. Notably, some features mentioned about cloud selection, adoption, and migration were described using different terms to refer to the same underlying concept. Similar features were consolidated to address this, reducing redundancy and improving coherence. Additionally, similarities observed across the selection, adoption, and migration aspects were combined to present a comprehensive list of valuable features. All extracted data, including features and techniques, were categorized to enhance readability and search ability.

For a comprehensive overview of the collected data, definitions, and phases, please refer to the Mendeley Data repository (Bieger, 2023). The subsequent section presents the results derived from the Systematic Literature Review.

4.5.1 Deployment & delivery models

In Chapter 2, we introduced the deployment and delivery models. Deployment and delivery models are critical aspects of cloud computing that significantly impact the efficiency, scalability, and accessibility of cloud-based services and applications. These models define how cloud resources are provisioned, managed, and made available to end-users, and they can have profound implications for both service providers and consumers (Vaquero, Rodero-Merino, Caceres, & Lindner, 2008). We have extracted the number of papers mentioning these models to estimate their popularity. This information will be useful when examining the services provided by CSPs. The results are shown in Table A.1.

4.5.2 Features

As depicted in the conceptual model presented in Figure 2.3, features play a crucial role in our framework. The features and services offered by cloud providers play a vital role in the adoption and success of cloud computing. These offerings determine the capabilities and functionalities available to organizations and can significantly impact the performance, security, and cost-effectiveness of cloud-based applications and services (Armbrust et al., 2010). To determine the essential features, we relied on insights obtained from our expert interviews, which helped validate their significance and relevance.

During the process of data extraction, we identified a total of 50 features. These features were gathered to cover the selection, adoption, and migration domains within cloud computing. We examined various research papers focusing on cloud service selection, adoption, and migration to ensure a comprehensive understanding of the essential features. The identified features primarily encompass both quality-related attributes and process-oriented characteristics. Table A.2 presents a complete list of all the features. The frequency values in the table indicate the number of times the features were mentioned in the literature. For detailed definitions of these features, please refer to the Mendeley Data repository (Bieger, 2023).

4.5.3 Techniques

We further analyzed the literature during data extraction to identify various models associated with cloud adoption, selection, and migration. This information is essential for organizations considering or already engaged in cloud adoption. Firstly, understanding the various selection criteria for cloud providers and services helps businesses make informed decisions that align with their specific needs, performance requirements, and budget constraints. Secondly, having insights into migration techniques enables a smooth transition of applications and data to the cloud, minimizing disruptions and potential risks. Lastly, learning about adoption techniques and best practices empowers organizations to maximize the benefits of cloud computing, optimize resource utilization, and ensure successful integration with existing IT infrastructure. This analysis provided valuable insights into commonly employed methods, thereby aiding us in selecting an appropriate approach for our research.

In total, we identified 81 techniques, including 57 techniques for selection, as presented in Table A.4, 16 techniques for adoption, as shown in Table A.3, and eight techniques for migration, as displayed in Table A.5. It is important to note that we have only included techniques mentioned more than once in the literature for the selected features. The acronyms used in the tables can be referred to in the Mendeley Data repository (Bieger, 2023), where detailed definitions are provided.

4.5.4 Cloud providers

The primary objective of identifying CSPs was to ascertain the providers to be included in the decision model for comparison, with the ultimate aim of identifying the optimal cloud solution. A comprehensive list comprising a total of 72 CSPs was compiled through an extensive review of the literature.

Table A.6 and A.7 present a comprehensive overview of the identified CSPs, categorized based on their respective delivery and deployment models. Among the recognized providers, 22 offer PaaS, 18 provide SaaS, and 46 offer IaaS delivery models. The study identified 36 public, 46 private, 25 hybrids, and four community CSPs regarding deployment models. These findings lay a robust foundation for further analysis and comparison within the study.

A validation process will be undertaken during the expert interviews to refine the selection of CSPs for in-depth investigation. This validation will involve assessing the range of services each provider offers and evaluating their ability to meet the identified requirements. Due to the vast number of CSPs available, it may not be feasible to assess all of them. Nevertheless, by prioritizing the most widely used and relevant CSPs, the decision framework is expected to achieve a high level of accuracy in evaluating and comparing potential cloud solutions.

4.6 Related work

This section provides a comprehensive overview of the evaluation of cloud service selection, situating the proposed decision model within the existing literature. The evaluation process was conducted using snowballing and systematic literature review as the primary methods to explore the literature on cloud computing and strategies addressing the cloud service selection problem. Figure 4.1 showcases a subset of selected studies that specifically address the challenge of selecting cloud services.

The selected studies are evaluated according to several criteria, including the year of publication, the use of multicriteria decision making techniques (MCDM), the application domain, the incorporation of the CSP combination into its framework, the use of quality characteristics, the number of features considered (Feat.), the number of alternatives evaluated (Alt.), the number of similar characteristics (#CF), the number of similar alternatives (#CA), and the coverage of our study in relation to the other studies (Cov.%). The coverage is computed using the formula:

$$Coverage = \frac{\#CF + \#CA}{Feat. + Alt.} * 100$$

.

This coverage metric provides an indication of how well our study aligns with the features and alternatives considered in the other studies, taking into account their similarities.

4.6.1 Evaluating Cloud Service Selection

The majority of research papers in the field of cloud service selection employ MCDM approaches or methodologies. Our study also utilizes the MCDM methodology to develop a decision model in line with this trend. Among the available methods for calculating the

Study	Year	MCDM	Domain	Combination	Quality feat.	Feat.	Alt.	#CF	#CA	Cov. (%)
This study	2023	Yes	Multi-cloud	Yes	No	345	17	345	17	100
(Ramamurthy, Saurabh, Gharote, & Lodha, 2020)	2020	Yes	Multi-cloud	Yes	Yes	5	4	2	3	56
(Jatoth, Gangadharan, Fiore, & Buyya, 2019)	2019	Yes	Single cloud	No	Yes	5	7	1	4	42
(Nawaz et al., 2018)	2018	Yes	Single cloud	No	Yes	4	1	2	1	60
(Abdel-Basset et al., 2018)	2018	Yes	Single cloud	No	Yes	5	3	2	2	50
(Youssef, 2020)	2020	Yes	Single cloud	No	Yes	9	8	6	4	59
(Rehman, Hussain, & Hussain, 2014)	2014	Yes	Single cloud	No	Yes	4	1	1	1	40
(Gireesha, Kamalesh, Krithivasan, & Sriram, 2022)	2022	no	Single cloud	No	Yes	9	12	7	1	38
(Farshidi, Jansen, De Jong, & Brinkkemper, 2018)	2018	Yes	Single cloud	No	Yes	119	39	57	11	43
(Sundareswaran, Squicciarini, & Lin, 2012)	2012	No	Single cloud	No	Yes	10	8	7	7	78
(Mandal & Khan, 2022)	2021	Yes	Single cloud	No	Yes	21	6	10	5	56
(Saha et al., 2021)	2021	Yes	Single cloud	No	Yes	20	3	8	3	48

Table 4.1: Related work

optimal cloud service provider, the Analytic Hierarchy Process (AHP), Fuzzy Logic, and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) are the most frequently encountered ones, as shown in Table A.4.

AHP, introduced by Thomas Saaty in the 1970s, is a widely adopted MCDM technique that enables the systematic analysis of complex decisions through hierarchical modeling. This process involves breaking down a decision problem into a hierarchy of criteria and sub-criteria, establishing their relative importance through pairwise comparisons, and synthesizing the judgments to obtain a priority ranking of alternatives(Saaty, 1980).

Fuzzy Logic, on the other hand, provides a mathematical approach to address uncertainties and imprecision in decision-making problems. Incorporating linguistic variables and fuzzy sets enables decision-makers to handle incomplete and ambiguous data effectively. Fuzzy logic proves to be particularly valuable when dealing with subjective and qualitative data, as it allows for the inclusion of expert opinions and linguistic terms in the decision-making process (Zadeh, 1965).

TOPSIS is another MCDM technique for ranking alternatives based on their proximity to the ideal solution. The method assumes that the best alternative is the one closest to the positive ideal solution and farthest from the negative ideal solution. The positive ideal solution represents the best values for each criterion, while the negative ideal solution represents the worst values (Hwang, Yoon, Hwang, & Yoon, 1981).

However, our research deviates from standard practice by incorporating requirements rather than relying solely on QoS in decision-making. This distinction sets our work apart from most papers and leads us to choose the WSM as the preferred calculation approach, as explained in Chapter 6.5.

While QoS attributes are commonly obtained from online databases and used for calculation, the transparency of the cloud service provider marketplace is limited, with a lack of comprehensive information regarding QoS (Sun et al., 2014). We opted for different types of features based on the requirements of organizations gathered from the expert interviews. This offers incredible tangibility and practicality, especially when involving organizational decision-makers.

The scarcity of multi-cloud decision models distinguishes our research from the existing literature. While numerous models focus on single cloud service selection, our work addresses the needs of organizational decision-makers in a multi-cloud environment. Additionally, our study stands out by considering a more extensive set of features than papers that utilize fewer criteria, mainly due to the computational complexity associated with MCDM techniques. By employing a more straightforward yet effective computation method, the WSM, we can evaluate a broader range of features, enhancing the comprehensiveness of our decision model.

Moreover, it should be noted that other papers have a significant number of criteria based on IaaS properties, such as response time and processing speed. Therefore, the coverage of similar features is lower for some of the papers presented in Figure 4.1. However, expert interviews also mention that IaaS properties are considered a thing of the past, and current providers are very similar in performance, which makes searching for an optimal cloud service provider different from a few years back. Hence, our approach of considering different requirements shows new importance in the cloud service selection domain.

It is crucial to emphasize that Farshidi (2020) has developed a comprehensive theoretical framework with the primary purpose of assisting software engineers in tackling challenges related to multiple criteria decision-making (MCDM) during software production (Farshidi, 2020). This framework presents a systematic approach to extract and consolidate knowledge from diverse sources, thereby facilitating the creation of decision models tailored to MCDM problems in software production. Building upon this framework, the researchers have successfully developed decision models for various software-related domains. For instance, they have applied it to the selection of cloud service providers in software production (Farshidi et al., 2018) and to the selection of Business Process Modeling Languages (BPMLs) for research modelers (Farshidi, Kwantes, & Jansen, 2023). These applications demonstrate the versatility and adaptability of the framework to address decision-making challenges in different software domains.

4.6.2 Multi-Cloud Approaches

As mentioned previously, the literature on multicloud decision making is limited, as indicated by the scarcity of comparable work in Figure 4.1. This scarcity highlights the need for further investigation in this area.

Within our scope, a multicloud framework paper was related and depicted in Figure 4.1. The paper delves into the critical task of selecting appropriate cloud service providers for hosting web applications in multi-cloud environments (Ramamurthy et al., 2020) The primary objective of this study is to develop a comprehensive decision-making framework encompassing a wide range of factors and criteria, incorporating both technical and business-related considerations. By integrating these essential criteria within their decision model, the authors aim to establish a holistic approach that effectively tackles the multifaceted challenges of selecting suitable cloud service providers for web application hosting in a multi-cloud context. It is worth noting that this research primarily focuses on web application hosting, whereas our study extends beyond that and encompasses the overall service capabilities of cloud service providers, leading to distinct requirements and considerations. However, this paper also shows the importance of looking from a combination perspective and considering various requirements.

In a related study by Omerovic and Radojevic (2013), the authors highlight the challenges posed by decision support for multi-cloud environments compared to traditional model-based decision support. They emphasize the dynamic nature of multi-cloud environments, which necessitates lightweight processes and tools. Decision-makers in such settings rely on easily understandable representations of the impacts of their decisions. Additionally, the trade-off analysis of enterprise and software architectures in multi-cloud environments places less emphasis on cost considerations. Furthermore, consolidating risk, cost, and quality aspects into a unified view presents new complexities and methodological challenges (Omerovic, Muntés-Mulero, Matthews, & Gunka, 2013).

Other works within the domain of multi-cloud computing provide comprehensive overviews, offering insights into architecture, challenges, benefits, management approaches, and potential applications (Imran et al., 2020; Hong et al., 2019).

4.7 Document analysis

This section encompasses the review of grey literature due to the scarcity of white papers focused explicitly on multi-cloud. Initially, the concept of multi-cloud will be elucidated from a company perspective, providing a comprehensive understanding of its implications and significance. Following this, the benefits of adopting a multi-cloud environment will be outlined, highlighting its advantages to organizations. Subsequently, the requirements for successfully implementing a multi-cloud environment will be expounded upon, providing organizations with essential considerations and guidelines. Finally, infrastructure as code will be explored as a valuable tool for establishing and managing a multi-cloud environment, offering insights into its practical application and benefits.

4.7.1 Multi-cloud

Multi-cloud, as stated in chapter 2, is when an organization uses cloud computing services from at least two cloud providers. This gives organizations greater flexibility and can help avoid vendor lock-in by enabling them to select the best services from multiple providers for specific applications or workloads (Google, 2023). Using various systems and applications best suited for your organization could also be essential for organizations looking to get ahead of their competition (Talend, 2023). Multi-cloud integrates IaaS, PaaS, and SaaS and considers networking, performance, security, operational management, and total cost of ownership (Oracle, 2023). In practice, multi-cloud typically means organizations using applications on PaaS or IaaS from multiple CSPs. It can also use SaaS from different cloud vendors, e.g., Salesforce (IBM, 2023b).

4.7.2 Benefits of multi-cloud

Chapter 2 already shows the benefits of multi-cloud defined by literature. Grey literature also describes multiple benefits.

1. **Best of each cloud**: Organizations can match specific features and capabilities using multiple CSPs to obtain an optimal cloud environment based on speed, reliability, security, performance, geographical location, and compliance (Google, 2023).

2. **Avoiding vendor lock-in**: In a multi-cloud environment, an organization is not dependent on one CSP. Relying on a single CSP could result in situations in which their data and metadata are shaped by the CSP their systems and protocols (Talend, 2023). Multi-cloud reduces data, interoperability, and cost issues due to the organization not adapting to a single CSP but standardizing its processes (Google, 2023).

3. **Cost optimization**: Using multi-cloud environments can be an effective strategy to reduce your IT expenses. Using public cloud services, you can minimize overhead costs while scaling resources up or down based on your requirements. This approach can help you reduce your total cost of ownership (TCO) and benefit from the optimal pricing and performance combinations available from various cloud providers (Google, 2023).

4. **Increased reliability and redundancy**: Maintaining all cloud resources within a single hosting environment has risks due to potential service disruptions or downtime, which causes your entire organization its productivity to stop (Google, 2023). However, organizations can mitigate these risks by adopting a multi-cloud environment by incorporating failover mechanisms across multiple cloud providers (Talend, 2023).

5. **Innovative technology**: CSPs continuously allocate substantial resources to advance their product portfolios and expand service offerings. Adopting a multi-cloud approach empowers organizations to capitalize on emerging technologies as they become available, thereby not relying solely on a single cloud provider's offerings, granting them the flexibility to leverage the latest innovations and stay at the forefront of technological advancements (Google, 2023).

6. **Advanced security and regulatory compliance**: Multi-cloud enables the deployment and scalability of workloads while ensuring consistent enforcement of security policies and compliance technologies across all workloads, irrespective of service, vendor, or environment. This approach allows organizations to establish a cohesive and standardized framework for safeguarding their workloads, thereby enhancing overall security and compliance across the entire multi-cloud environment (Google, 2023).

4.7.3 Requirements for multi-cloud

Designing a multi-cloud environment needs multiple architectural decisions, such as network latency, data flows, security, orchestration, and operational management.

1. **Latency** for apps should be minimized. Depending on the application used, the prohibited latency can vary. The integrations like API and database communication should suit the given latency requirements (Oracle, 2023).

2. **Data flows** should be able to handle big volumes of data across clouds. The costs for data transfers typically are in outgoing data and not incoming. These costs vary per CSP. Compliance and data location vary between providers and should be considered (Oracle, 2023).

3. **Security** within a multi-cloud environment could get complex. All cloud providers provide various tooling and suppliers, which could lead to complex security policies and more security staff. To organize this efficiently, organizations should reevaluate their security and seek the best service for their environment. Also, external suppliers could help integrate an optimal security strategy. With APIs and partnerships between CSPs, an optimal security strategy could be created (Oracle, 2023).

4. **Orchestration** of the multi-cloud architecture and managing them is essential. Due to the multiple tools available, it is difficult for in-house IT staff to be an expert in everything. Using the proper automation tooling to work in every cloud is important. Infrastructure as code is essential to maximize availability, scalability, flexibility, and cost optimization (Oracle, 2023). Improving your prior infrastructure to move to a multi-cloud environment could get complex and needs integration with initial infrastructure and maintenance (Talend, 2023)).

5. **Managing** the multi-cloud environment is already mentioned in prior items, but standardizing the cloud platforms is essential for efficiently organizing people, processes, and tooling (Oracle, 2023). Therefore, e.g., containerization and microservices are important (Talend, 2023). Containerization and microservices enable organizations the flexibility to move applications between clouds, which let the organization achieve their digital transformation goals (SageIT, 2023).

6. **Compliance** holds significant importance, and CSPs must align their compliance standards with the policies set forth by organizations. The harmonization of compliance

requirements between CSPs and organizations facilitates the establishment of a cohesive framework that upholds regulatory obligations, industry standards, and internal governance protocols(Google, 2023).

7. **Compatibility** is essential when establishing a multi-cloud environment. In a multi-cloud environment, APIs may differ per CSP by distinct structures or programming languages, necessitating intricate customization efforts. Furthermore, in the context of data storage services, compatibility across multiple clouds mandates the adoption of consistent data structures to ensure seamless integration and interoperability (Dgtlinfra, 2023).

4.7.4 Infrastructure as code

Infrastructure as Code (IaC) is an approach to managing and provisioning computing infrastructure resources through machine-readable, declarative configuration files, scripts, or code. IaC plays a pivotal role in the adoption of DevOps principles and the implementation of continuous integration/continuous delivery practices. By using IaC, developers are relieved of manual provisioning tasks, as they can execute scripts to swiftly configure the required infrastructure for their multi-cloud environment (RedHat, 2023).

This approach ensures that lengthy infrastructure setup procedures do not hinder application deployments, enabling a streamlined and efficient deployment process. Simultaneously, system administrators are freed from managing labor-intensive manual operations associated with infrastructure provisioning (RedHat, 2023).

IaC requires training since a certain learning curve comes with adopting new technology. Currently, the combination of skills with IaC and DevOps is highly sought after due to its many benefits (Roper, 2023).

Within the last section (Requirements for multi-cloud), it was already mentioned that IaC was necessary for the orchestration of a multi-cloud environment since it can reduce costs, speed up deployments, reduce errors, improve infrastructure consistency, and eliminate configuration drift (Red Hat). CSPs provide their own IaC, such as ARM from Azure or AWS CloudFormation from AWS, but also third-party platforms exist like Terraform, Ansible, Chef, and Pulumi (Microsoft). Organizations should pick a suitable IaC platform, and the following factors should be considered (Abdullahi, 2023):

1. **Automation**: The implementation of automation mitigates the risks associated with human error from manual processes involved in deploying, configuring, and managing infrastructure. By adopting automated deployment practices, organizations can effectively minimize costs by minimizing errors, enhancing operational velocity, and optimizing workload efficiency. IaC tools offer various automation features, so an organization should compare the different products.

2. **Scalability**: DevOps best practices emphasize seamless up and downscaling to accommodate fluctuating demands in resources. An organization should pick an IaC tool that has scalability functionalities such as dynamic orchestration and auto-scaling capabilities. By doing so, organizations can ensure that their environments possess adequate resources to accommodate existing and anticipated demands.

3. **Cost**: IaC tools enable organizations to save costs compared to manual setup and maintenance of infrastructure. To optimize cost efficiency while addressing organizational priorities, it is crucial to select an IaC tool that matches the organization's requirements. Pricing models and licensing fees vary among the different vendors.

4. **Integration and extensibility**: IaC tools should prioritize the availability of comprehensive integration and extensibility options. They should have suitable APIs facilitating seamless integration with external services and systems. Also, an extensive library of plugins is important as this enables the augmentation of the tool's inherent capabilities. Lastly, extensibility options empower organizations to develop custom integrations and connectors if needed.

5. **Security and support**: IaC tools provide numerous security features such as identity access management, encryption, and data loss prevention. Additionally, customer service and technical support could be beneficial throughout the implementation and adoption journey. An organization should find the suitable customer service and security requirements.

Chapter 5

Expert interviews

The interviews conducted for this study were conducted in two distinct phases. The first phase encompassed seven interviews, while the second phase involved five interviews. The primary objective of the initial phase was to gather in-depth domain knowledge about cloud service providers, essential features, and the intricacies of multi-cloud environments. During this phase, the foundational decision model was established. A preliminary decision model was developed between the two phases based on the information gathered.

The second phase of the interviews focused on validating and finalizing the decision model. The protocols for both stages of the discussions can be found in Appendix B.1 and B.2, respectively. The analyzed data can also be accessed in the Mendeley data repository (Bieger, 2023).

5.1 Results: Phase One

This section presents the results of the first phase of the research, focusing on the topics of CSP experience, provider evaluation, feature assessment, and considerations related to multi-cloud environments. The findings are based on interviews conducted with experts from various organizations, as detailed in the research protocol shown in Appendix B.1.

5.1.1 CSP Experience

During the interviews, the experts were questioned about their prior experience with different CSPs. Most participants reported extensive experience with Microsoft Azure, while a significant portion had worked with AWS. A smaller subset of participants mentioned their familiarity with GCP, and one participant had hands-on experience with IBM Cloud.

This diversity in experience indicates that Azure and AWS are the most commonly used CSPs among the experts' organizations, while GCP and IBM Cloud have a more limited presence. This finding reflects the current market trend, where Azure and AWS dominate the cloud computing industry.

5.1.2 Provider Evaluation

The process of selecting appropriate CSPs for inclusion in the decision model began with identifying and validating potential candidates. Tables A.6 and A.7 served as references for this purpose. The validation process led to selecting 15 CSPs as initial candidates, and IBM and OVHcloud were included based on their significance, as highlighted by domain experts.

The experts provided valuable insights into the distinguishing capabilities of various CSPs. Presently, Azure holds a prominent position in the European market, with a significant number of organizations utilizing Azure and AWS as their preferred infrastructure providers. However, the study emphasizes that each cloud provider has unique selling points that justify their existence in the market. While larger CSPs like AWS, Azure, and GCP offer a comprehensive range of features and services, smaller cloud providers focus on catering to more specific needs. For example, Salesforce primarily provides software solutions for customer relationship management.

Looking ahead, the experts identified the integration of clouds and compliance as increasingly crucial factors shaping the future landscape of the CSP industry. Specific policies in countries like Germany prioritize the selection of cloud providers located within the country and compliant with C5 regulations. Additionally, indications suggest the emergence of a European cloud provider that could address the growing demand for compliance-oriented services within the region.

It is evident from the findings that the cloud computing industry is dynamic, with evolving trends and opportunities for various CSPs. While Azure and AWS dominate the European market, other CSPs possess unique strengths and value propositions that cater to specific organizational requirements. The future trajectory of the CSP industry is likely to be influenced by the growing importance of integration and compliance, which may pave the way for the emergence of a prominent European cloud service provider.

5.1.3 Feature Assessment

During the interviews, the experts were presented with a comprehensive set of questions and provided a list of various CSPs, their respective features, quality attributes, and compliance standards. The discussions emphasized the significance of leveraging legacy knowledge to its fullest extent, necessitating optimal integration between the chosen CSP and the organization's existing systems. Aligning the selected CSP with the organization's long-term roadmap and strategic objectives was also emphasized.

Cost considerations emerged as a crucial factor in the decision-making process. The cost of services varies among different CSPs, including licensing fees. While obtaining more licenses from a single CSP may result in cost savings, it may also introduce the risk of vendor lock-in, potentially limiting future flexibility and choice.

Among the features evaluated, the experts identified security, disaster recovery, and robust data management capabilities as the most critical. Ensuring stringent security measures, implementing robust disaster recovery plans, and possessing comprehensive data handling capabilities were essential characteristics for a reputable CSP.

Overall, the expert insights highlighted the significance of optimal integration with legacy systems, alignment with the organization's long-term strategy, cost considerations, and potential vendor lock-in, as well as the vital importance of security, disaster recovery, and data management capabilities in the selection of a suitable CSP for the organization's cloud requirements.

5.1.4 Multi-cloud Considerations

To establish a multicloud environment, experts unanimously emphasized the importance of aligning with the organization's existing legacy systems regarding programming languages, database systems, and operating systems. Furthermore, the cloud provider should have a notable presence in the region, demonstrated through consultancy partnerships and the availability of skilled employees that the organization can potentially hire. It is crucial for the chosen cloud provider to support containerization, as this facilitates seamless data transfer between tenants within the multi-cloud environment.

Moving towards a multi-cloud approach requires a robust business case to justify the complexity and associated expenses. One compelling business case highlighted by experts is that multi-cloud can serve as an effective exit strategy. Integration capabilities between different cloud providers are essential for ensuring smooth interoperability and streamlined operations.

Additionally, providers should offer the option to bring their licenses, as this reduces costs and provides flexibility and continuity for organizations with existing licenses.

Establishing a multi-cloud environment requires careful consideration of existing legacy systems, regional popularity and partnerships, containerization support, a solid business case, integration capabilities, and license portability. By addressing these factors, organizations can navigate the complexities and effectively leverage the benefits of a multi-cloud approach.

5.1.5 Conclusion

The first phase of the research has provided valuable insights into cloud service provider experience, evaluation, feature assessment, and multi-cloud considerations. Azure and AWS emerged as dominant players in the European market, but other CSPs offer unique strengths and cater to specific needs. The integration of clouds and compliance were identified as pivotal factors shaping the future of the CSP industry.

The feature assessment highlighted the importance of optimal integration, cost considerations, and essential security and disaster recovery capabilities. In the context of multi-cloud environments, aligning with existing legacy systems, creating a compelling business case, and ensuring integration capabilities were emphasized.

In the next phase, the research will delve deeper into individual CSPs' specific characteristics and capabilities. This comprehensive approach will offer organizations valuable insights for making informed decisions in their multi-cloud adoption journey.

5.2 Results: Phase Two

This section presents the results of the second phase of the research, which further explores CSP experience, provider evaluation, decision model assessment, and considerations related to multi-cloud environments. The findings are based on interviews conducted with a panel of five experts from various organizations, as detailed in the research protocol shown in Appendix B.2.

5.2.1 CSP Experience

Among the panel of experts, a notable level of familiarity was observed with Microsoft Azure, with all experts possessing a degree of proficiency in its usage. Additionally, the majority of experts demonstrated significant understanding and experience with GCP, AWS, and Alibaba Cloud. Furthermore, one or two experts had prior experience working with other cloud services providers, such as IBM Cloud, Oracle Cloud, and VMware.

This diverse range of experiences indicates that the cloud computing landscape is characterized by multiple prominent players, each with its own strengths and offerings. While Azure remains a popular choice among the experts, other major CSPs like GCP, AWS, and Alibaba Cloud also hold substantial market presence and are widely adopted by organizations.

5.2.2 Provider Evaluation

The cloud service providers evaluated in this study exhibited a comparable level of customer experience at the infrastructure level, with no significant performance disparities identified at present. However, notable distinctions arise regarding the SaaS applications offered by each provider. Variances in unique selling points (USPs) were observed, ranging from specialized cloud service providers like Salesforce to larger providers such as AWS, Azure, and GCP, which offer comprehensive coverage of various features.

The experts in this study collectively envision compliance and technological advancements as the foundational drivers of change within the cloud computing domain. These factors potentially open up possibilities for the emergence of a prominent European cloud service provider, exemplifying the evolving landscape of the cloud computing industry.

As revealed by our findings, the utilization of techniques in multi-cloud environments shows that most domain experts did not employ any specific methods. Instead, the process often involves manual decision-making based on experience or the organization issuing a tender, allowing cloud service providers to submit their proposals and offerings in response. This implies that multi-cloud strategies are adopted based on individual, organizational preferences and requirements rather than a standardized approach.

5.2.3 Decision Model Assessment

The decision model was initially constructed during the first phase and subsequently refined through an iterative process in the second phase. All existing features were deemed significant and validated as integral components through a comprehensive evaluation. Several recommendations were put forth, highlighting areas for potential enhancements. The experts noted that while the level of detail about cloud services was lacking, the USP section successfully addressed this limitation by providing valuable insights into the unique offerings of each CSP. The API category was acknowledged as being highly technical but potentially enlightening for a comprehensive understanding. Although the combination examples provided were deemed extensive, the experts acknowledged their informative value. Notably, an assessment of infrastructure-scale performance was deemed unnecessary due to the prevailing similarity among CSPs during the current period.

Additionally, various suggested features, including discounts and managerial functionalities, were proposed for potential inclusion in the decision model. However, incorporating these suggested features was hindered by a lack of transparency from some CSPs, making it challenging to evaluate and compare these aspects across providers precisely.

5.2.4 Multi-cloud Considerations

The experts have indicated various interpretations of multi-cloud; however, they assert that most organizations employ a multi-cloud approach wherein a single infrastructure is utilized alongside multiple SaaS offerings to enhance functionality. The decision to pursue various infrastructures necessitates a specific business case due to the intricacies and usability concerns. Cost considerations play a crucial role in achieving savings and optimizing costs.

Furthermore, cloud service providers must facilitate utilizing in-house knowledge and expertise to ensure a smooth transition to a multi-cloud environment. Adopting a multi-cloud strategy also serves as an exit strategy, as relying solely on one vendor may result in vendor lock-in, where the entire organization becomes dependent on that particular vendor. Consequently, third-party platforms, such as Terraform, are of importance in supporting the integration of multiple cloud providers.

5.2.5 Conclusion

The second phase of the research has provided valuable insights into the experience with various CSPs, provider evaluation, decision model evaluation, and considerations for multi-cloud environments. The diverse experiences with different CSPs emphasize the competitive nature of the cloud computing market. Additionally, the findings underscore the importance of compliance, technological advancements, and integration capabilities in shaping the future of cloud computing. As organizations continue to navigate the complexities of cloud adoption, understanding the unique offerings of each CSP and the strategic implications of multi-cloud approaches will be crucial for making informed decisions that align with their long-term objectives and requirements. The next Chapter discusses the foundational elements from the expert interviews to develop the decision model. This carefully crafted model will be a cornerstone for conducting real-world case studies, enabling organizations to gain deep and comprehensive insights that are crucial for developing effective cloud adoption strategies. Moreover, these case studies will also rigorously assess and validate the model's reliability and applicability in practical scenarios.

Chapter 6

The decision model

The construction of the decision model used a combination of literature research and interviews to gather relevant information. Through an iterative process during the interviews, the decision model was gradually developed, capturing essential features to consider when selecting CSPs for a multi-cloud environment. The decision model is based on the decision model shown in the framework in figure 2.3. The decision model encompasses three distinct sections, namely:

- CSP features: In this section, the decision model directs its attention towards the identification and definition of critical features and requirements essential for an organization's multi-cloud strategy. These features encompass a range of factors including business requirements, in-house knowledge, and combination enablement. By defining and understanding these key features and requirements, organizations can effectively assess and compare cloud providers to make informed decisions that align with their multi-cloud strategy.

- Alternatives: This section is dedicated to profiling and evaluating various CSPs available in the market. It includes a thorough description of different CSPs incorporated in the decision model. This assessment aims to provide a comprehensive understanding of each CSP's strengths and weaknesses, allowing decision-makers to align the features identified in the previous section with the most suitable CSPs.
- Feasible combination mapping: Multi-cloud strategies often involve using multiple CSPs to leverage each provider's strengths and mitigate potential risks. In this section, the decision model delves into the exploration of different combinations of cloud providers by examining both use cases and strategic partnerships. Through the exploration of both use cases and strategic partnerships, the decision model assists organizations in identifying and selecting the most suitable combinations of cloud providers for their multi-cloud strategies.

By delineating these three sections, the decision model provides a structured approach for evaluating CSPs in a multi-cloud environment, taking into account features, cloud providers, and a combination of potential cloud providers. The following section elucidates the methodology employed for data acquisition, detailing the systematic approach adopted to gather relevant information and datasets. The final section expounds on the computational procedures and algorithms utilized for assessing the suitability of CSPs within the decision model. In this section, we explicate the methodological approaches employed for calculating the decision model.

6.1 CSP features

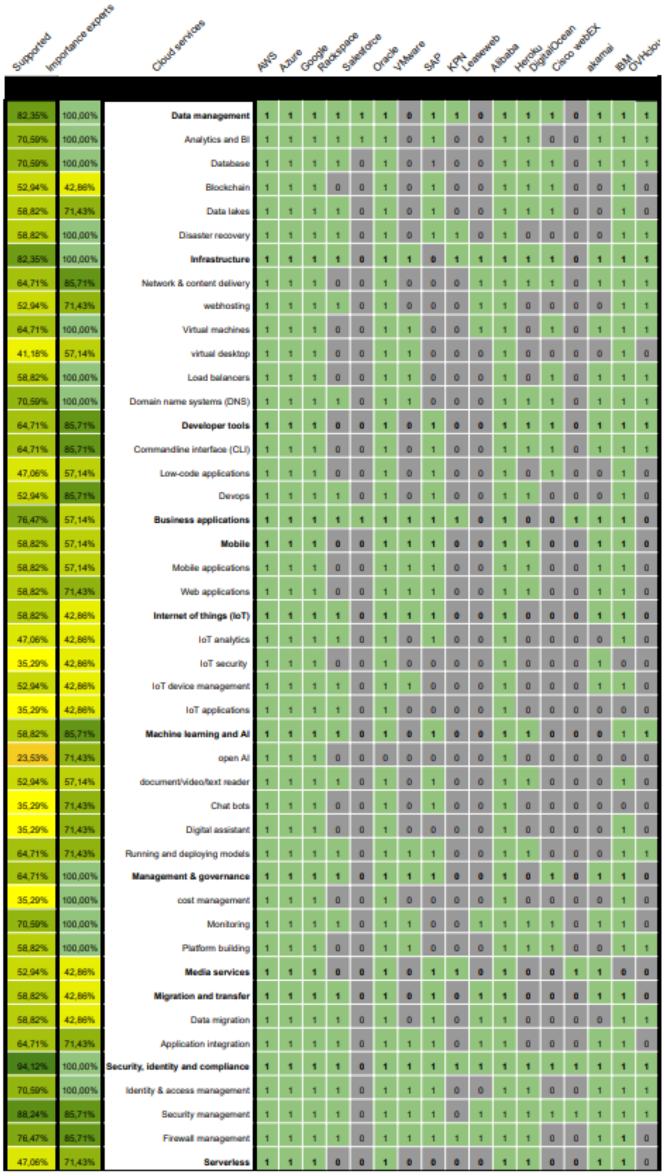
6.1.1 Business requirements

To establish a multi-cloud environment, experts assert that a clear business case is imperative. To align a CSP with the specific business requirements of an organization, the following key features are considered for this decision model: Cloud services, Service license agreement (SLA), USP, Costs, Customer ratings, Data center location and compliance. By considering these features, organizations can make informed decisions when selecting a CSP that best meets their business requirements for establishing a multi-cloud environment.

Cloud services

CSPs offer a wide array of specialized products and services designed to cater to the unique requirements of organizations. The significance of these services may vary depending on each organization's specific context and objectives. Each cloud service comes with its distinct set of functionalities and features. Thus, a strategic selection process is crucial, aligning the chosen services with the organization's business needs and overarching goals. This meticulous alignment ensures that the selected cloud services directly contribute to achieving strategic objectives and effectively support the organization's core mission. As part of this process, comprehensive identification and analysis of different categories of cloud services are undertaken across multiple CSPs. This systematic evaluation allows organizations to make informed decisions regarding the most suitable CSPs and their services, fostering a successful cloud adoption journey.

Figure 6.1 presents a comprehensive overview of the cloud services, encompassing the full spectrum of offerings using boolean values. All cloud services are examined to ascertain the offerings and capabilities provided by different CSPs. The figure further includes the percentages representing the level of support for each feature and the corresponding percentages denoting the perceived importance of these features as indicated by the experts who were interviewed during the initial phase of the study.



Supported	Importance experts	Cloud services	AWS	Azure	Google	Rackspace	Salesforce	Oracle	VMware	SAP	KPN	Leaseweb	Alibaba	Heroku	DigitalOcean	Cisco webEX	akamai	IBM	OVHclou
82,35%	100,00%	**Data management**	1	1	1	1	1	1	0	1	1	0	1	1	1	0	1	1	1
70,59%	100,00%	Analytics and BI	1	1	1	1	1	1	0	1	0	0	1	1	0	0	1	1	1
70,59%	100,00%	Database	1	1	1	1	0	1	0	1	0	0	1	1	1	0	1	1	1
52,94%	42,86%	Blockchain	1	1	1	0	0	1	0	1	0	0	1	1	1	0	0	1	0
58,82%	71,43%	Data lakes	1	1	1	1	0	1	0	1	0	0	1	1	1	0	0	1	0
58,82%	100,00%	Disaster recovery	1	1	1	1	0	1	0	1	1	0	1	0	0	0	0	1	1
82,35%	100,00%	**Infrastructure**	1	1	1	1	0	1	1	0	1	1	1	1	1	0	1	1	1
64,71%	85,71%	Network & content delivery	1	1	1	0	0	1	0	0	0	1	1	1	1	0	1	1	1
52,94%	71,43%	webhosting	1	1	1	1	0	1	0	0	0	1	1	0	0	0	0	1	1
64,71%	100,00%	Virtual machines	1	1	1	0	0	1	1	0	0	1	1	0	1	0	1	1	1
41,18%	57,14%	virtual desktop	1	1	1	0	0	1	1	0	0	0	1	0	0	0	0	1	0
58,82%	100,00%	Load balancers	1	1	1	0	0	1	1	0	0	0	1	0	1	0	1	1	1
70,59%	100,00%	Domain name systems (DNS)	1	1	1	1	0	1	1	0	0	0	1	1	1	0	1	1	1
64,71%	85,71%	**Developer tools**	1	1	1	0	0	1	0	1	0	0	1	1	1	0	1	1	1
64,71%	85,71%	Commandline interface (CLI)	1	1	1	0	0	1	0	1	0	0	1	1	1	0	1	1	1
47,06%	57,14%	Low-code applications	1	1	1	0	0	1	0	1	0	0	1	0	1	0	0	1	0
52,94%	85,71%	Devops	1	1	1	1	0	1	0	1	0	0	1	1	0	0	0	1	0
76,47%	57,14%	**Business applications**	1	1	1	1	1	1	1	1	1	0	1	0	0	1	1	1	0
58,82%	57,14%	**Mobile**	1	1	1	0	0	1	1	1	0	0	1	1	0	0	1	1	0
58,82%	57,14%	Mobile applications	1	1	1	0	0	1	1	1	0	0	1	1	0	0	1	1	0
58,82%	71,43%	Web applications	1	1	1	0	0	1	1	1	0	0	1	1	0	0	1	1	0
58,82%	42,86%	**Internet of things (IoT)**	1	1	1	1	0	1	1	1	0	0	1	0	0	0	1	1	0
47,06%	42,86%	IoT analytics	1	1	1	1	0	1	0	1	0	0	1	0	0	0	0	1	0
35,29%	42,86%	IoT security	1	1	1	0	0	1	0	0	0	0	1	0	0	0	1	0	0
52,94%	42,86%	IoT device management	1	1	1	1	0	1	1	0	0	0	1	0	0	0	1	1	0
35,29%	42,86%	IoT applications	1	1	1	1	0	1	0	0	0	0	1	0	0	0	0	0	0
58,82%	85,71%	**Machine learning and AI**	1	1	1	1	0	1	0	1	0	0	1	1	0	0	0	1	1
23,53%	71,43%	open AI	1	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0
52,94%	57,14%	document/video/text reader	1	1	1	1	0	1	0	1	0	0	1	1	0	0	0	1	0
35,29%	71,43%	Chat bots	1	1	1	0	0	1	0	1	0	0	1	0	0	0	0	0	0
35,29%	71,43%	Digital assistant	1	1	1	0	0	1	0	0	0	0	1	0	0	0	0	1	0
64,71%	71,43%	Running and deploying models	1	1	1	1	0	1	1	1	0	0	1	1	0	0	0	1	1
64,71%	100,00%	**Management & governance**	1	1	1	1	0	1	1	1	0	0	1	0	1	0	1	1	0
35,29%	100,00%	cost management	1	1	1	0	0	1	0	0	0	0	1	0	0	0	0	1	0
70,59%	100,00%	Monitoring	1	1	1	1	0	1	1	0	0	1	1	1	1	0	1	1	0
58,82%	100,00%	Platform building	1	1	1	0	0	1	1	0	0	0	1	1	1	0	0	1	1
52,94%	42,86%	**Media services**	1	1	1	0	0	1	0	1	1	0	1	0	0	1	1	0	0
58,82%	42,86%	**Migration and transfer**	1	1	1	1	0	1	0	1	0	1	1	0	0	0	1	1	0
58,82%	42,86%	Data migration	1	1	1	1	0	1	0	1	0	1	1	0	0	0	0	1	1
64,71%	71,43%	Application integration	1	1	1	1	0	1	1	1	0	1	1	0	0	0	1	1	0
94,12%	100,00%	**Security, identity and compliance**	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1
70,59%	100,00%	Identity & access management	1	1	1	1	0	1	1	1	0	0	1	1	0	0	1	1	1
88,24%	85,71%	Security management	1	1	1	1	0	1	1	1	0	1	1	1	1	1	1	1	1
76,47%	85,71%	Firewall management	1	1	1	1	0	1	1	1	1	1	1	1	0	0	1	1	0
47,06%	71,43%	**Serverless**	1	1	1	0	0	1	0	0	0	0	1	1	0	0	1	1	0

Figure 6.1: Decision model: Cloud service

Service license agreement

According to CIO (Overby, 2017), an SLA is pivotal in defining a CSP's expected service provision standards. It delineates measurable criteria for assessing service quality and establishes prescribed actions or penalties in the event of service-level non-compliance. The SLA is crucial in specifying responsibilities, setting expectations, and facilitating a shared understanding of specifications and obligations about service-related challenges (Overby, 2017). These agreements outline the anticipated performance and availability of cloud services, making it imperative that organizations select services that align with their service-level expectations. By doing so, organizations can ensure that critical applications and services receive the requisite support and uninterrupted availability. Additionally, experts underscore the significance of considering the SLA and the CSP's approach to managing service-related complications while selecting a CSP. A well-considered assessment of SLAs and the CSPs' handling of service issues is fundamental to establishing a robust and mutually beneficial relationship between organizations and their chosen CSPs.

Within the decision model, the availability of SLAs was investigated. While most CSPs customize the SLA in collaboration with the customer, some CSPs show generic service standards. Most of the examined SLAs provided by cloud providers emphasized service availability and the corresponding service credits in case of availability disruptions. As shown in Figure 6.2, the availability thresholds varied, with categories such as 99% or higher, between 99% and 95%, lower than 95%, and some even below 90%.

Supported	SLA	AWS	Azure	Google	Rackspace	Salesforce	Oracle	VMware	SAP	KPN	Leaseweb	Alibaba	Heroku	DigitalOcean	Cisco webEX	akamai	IBM	OVHcloud
88.24%	Availability	1	1	1	1	1	0	1	1	1	1	1	0	1	1	1	1	1
	Uptime >99%	10%	10-25%	0%	20-25%	-	-	0%	0%	-	-	10%	-	10%	-	-	-	5-10%
	Uptime 95% - 99%	25-30%	25-50%	10%	30-100%	-	-	5-10%	2-10%	-	-	25%	-	25%	-	-	-	10-30%
	Uptime <95%	100%	30-100%	25%	30-100%	-	-	10-25%	10-100%	-	-	100%	-	100%	-	-	-	30-100%
	uptime <90%	-	-	50%	-	-	-	10-100%	20-100%	-	-	-	-	-	-	-	-	-

Figure 6.2: Decision model: SLA supported

Unique selling points

A USP represents a distinguishing factor that sets a product or service apart from its competitors. The significance of reputation, as indicated in Table A.2, has been emphasized in the literature. Moreover, during interviews, most participants also stressed the importance of USPs. Cloud providers often offer specialized services or offerings tailored to specific industries or use cases. By carefully assessing USPs, organizations can identify providers with solutions customized to meet their unique needs. Additionally, some cloud providers differentiate themselves through cutting-edge technologies and continuous innovation. Incorporating innovation-related USPs into decision-making enables organizations to future-proof their cloud strategy and maintain a competitive edge. Furthermore, certain cloud providers focus on serving specific industries and verticals, providing tailored services and support. Opting for a provider with relevant industry expertise enhances the likelihood of obtaining more customized solutions and a better understanding of the organization's requirements. Considering the USPs of cloud providers ensures that the organization's cloud strategy is closely aligned with its distinctive needs, leading to optimal outcomes and maximizing the benefits of cloud adoption.

To gather information about USPs, market evaluation companies such as Gartner, Forrester, and IDC were consulted for this decision model. Publicly available reports from 2022 were utilized in this process. Within the scope of this study, the providers were ranked based on their ability to execute compared to one another, as shown in Figure 6.3. The providers, if mentioned, were assigned rankings based on their ability to execute, ranging from 1 (best) to lower values. These rankings are visually represented using green for good performance and red for comparatively lower performance.

USP (2022)	AWS	Azure	Google	Rackspace	Salesforce	Oracle	VMware	SAP	KPN	Leaseweb	Alibaba	Heroku	DigitalOcean	Cisco webEX	akamai	IBM	OVHcloud	Source
Access management	-	1	-	-	-	3	-	-	-	-	-	-	-	-	-	2	-	gartner
Paas ranking	1	2	3	-	-	5	-	-	-	-	4	-	-	-	-	6	-	gartner
Ai developer services	1	2	3	-	-	6	-	-	-	-	5	-	-	-	-	4	-	gartner
Analytics and business intelligence platforms	5	1	3	-	2	5	-	6	-	-	4	-	-	-	-	7	-	gartner
Application performance monitoring and observability	1	3	-	-	-	7	5	-	-	-	6	-	-	2	-	4	-	gartner
Cloud for erp, service orientated	-	3	-	-	-	1	-	2	-	-	-	-	-	-	-	-	-	gartner
Cloud for erp, product orientated	-	2	-	-	-	1	-	3	-	-	-	-	-	-	-	-	-	gartner
Data management systems	1	2	4	-	-	3	-	5	-	-	6	-	-	-	-	7	-	gartner
Field service management	-	3	-	-	2	1	-	4	-	-	-	-	-	-	-	-	-	gartner
Procure-to-Pay Suites	-	3	-	-	-	1	-	2	-	-	-	-	-	-	-	-	-	gartner
network firewalls	4	3	-	-	-	-	-	-	-	-	2	-	-	1	-	-	-	gartner
security information and event management	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	gartner
Lowcode application platforms	-	1	-	-	2	3	-	-	-	-	4	-	-	-	-	-	-	gartner
Cost management & optimization	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	2	-	Forrester
Public Cloud Container Platforms	3	4	2	-	-	6	-	-	-	-	1	-	-	-	-	5	-	Forrester
API management	-	4	2	-	-	-	-	-	-	-	-	-	-	-	-	1	-	Forrester
Cloud development and infrastructure platforms	1	2	4	9	8	6	-	-	-	-	3	-	-	-	-	5	7	Forrester
Identity & access management	-	4	-	-	5	-	-	2	-	-	-	-	-	-	3	1	-	Forrester
Public cloud IaaS	1	2	3	-	-	4	-	-	-	-	5	-	9	-	8	6	7	IDC

Figure 6.3: Decision model: USP

Service cost forecasting

Experts underscore the importance of cost forecasting for a specific CSP tailored to an organization's requirements. Various cloud services encompass varying pricing models and cost structures. The judicious selection of services aligned with the organization's distinct needs contributes to cost optimization. Cost forecasting assumes critical significance during cloud selection for organizations, enabling informed decision-making regarding their cloud adoption strategy and budget allocation.

Cloud services often involve multiple pricing components, such as computing, storage, data transfer, and support. Forecasting costs aid in conducting a TCO analysis, encompassing upfront and ongoing expenses, to determine the most economically viable option. In assessing multiple cloud providers, cost forecasting facilitates a comparison of pricing structures and offerings among different vendors. This ensures the selection of a provider that best aligns with the organization's budgetary constraints and requirements.

To facilitate this into the decision model, the billing methods employed by the CSPs were examined, including pay-per-use, hourly, and monthly billing options. Additionally, certain CSPs offer the opportunity to calculate the TCO based on the organization's service needs. Some providers also provide cost optimization tools aimed at reducing expenses and assisting organizations in optimizing their cloud environment. Lastly, several CSPs offer the opportunity for organizations to avail themselves of a free trial period to test their services before committing to a paid subscription. Figure 6.4 comprehensively depicts the accessible data about service costs using boolean values.

Supported	Service costs (forcasting)	AWS	Azure	Google	Rackspace	Salesforce	Oracle	VMware	SAP	KPN	Leaseweb	Alibaba	Heroku	DigitalOcean	Cisco webEX	akamai	IBM	OVHcloud
41.18%	Pay per use	1	1	1	1	0	1	0	0	0	0	1	0	0	0	0	1	0
23.53%	Pay per hour	0	0	0	0	0	0	1	0	1	0	0	1	0	0	0	0	1
52.94%	Pay per month	0	0	0	1	1	0	0	1	0	1	0	1	1	1	1	0	1
64.71%	TCO calculator	1	1	1	0	0	1	1	1	0	0	1	1	1	0	1	1	0
64.71%	Cost optimisation	1	1	1	1	0	1	1	0	0	0	1	1	0	1	1	1	0
82.35%	Free trail	1	1	1	1	1	1	1	1	0	0	1	0	1	1	1	1	1

Figure 6.4: Decision model: Service costs forcasting

Cost estimates

The significance of service costs in the decision-making process is consistently underscored in the existing literature and by experts in the field. Cost estimates serve as a valuable tool, offering a comprehensive breakdown of the expenses associated with utilizing the services provided by each CSP. This transparency fosters a deep understanding of the underlying cost structure, enabling organizations to make well-informed decisions regarding their cloud expenditure.

Given that different CSPs present diverse pricing models, service bundles, and resource configurations, cost estimates play a crucial role in standardizing these offerings into comparable units. This standardization facilitates a more fair apples-to-apples comparison among the various providers. Additionally, by availing themselves of cost estimates, organizations can align potential cloud expenses with predefined budget constraints. It empowers them to evaluate and discern which CSP offers the most favorable value for money while remaining within their financial parameters.

Incorporating cost estimates into the decision model ensures that financial considerations are integral to the overall cloud selection process. It safeguards organizations from making decisions solely based on technical features without fully accounting for the financial repercussions. By holistically integrating cost estimates, organizations can strike an optimal balance between technical requirements and financial prudence, resulting in more sound and well-rounded cloud selection decisions.

Cost estimates were generated utilizing the TCO calculator to obtain a comprehensive comprehension of the current pricing structure of services. Within this decision model, the least expensive alternative was selected from the various components, including hourly virtual machine costs, per-gigabyte storage costs per hour, and per-gigabyte bandwidth costs. Furthermore, a small-scale usage scenario was considered, and the providers were evaluated based on low, medium, and high-cost indications to provide a comprehensive overview of their pricing levels. Figure 6.5 illustrates the concepts above. The data above provides a general sense of the pricing structure; however, it is essential to note that these prices are subject to variation in practice.

Cost estimates	AWS	Azure	Google	Rackspace	Salesforce	Oracle	VMware	SAP	KPN	Leaseweb	Alibaba	Heroku	DigitalOcean	Cisco webEX	akamai	IBM	OVHcloud
Cost estimates																	
VM (per hour)	0.05	0.06	0.07	0.08	0.09	0.07	0.08	0.07	0.06	0.09	0.08	0.1	0.06	0.09	0.07	0.08	0.07
Storage (per GB/month)	0.1	0.12	0.11	0.15	0.13	0.14	0.16	0.12	0.11	0.14	0.13	0.15	0.1	0.14	0.12	0.13	0.12
Bandwidth (per GB)	0.02	0.3	0.03	0.04	0.05	0.04	0.05	0.04	0.03	0.05	0.04	0.06	0.02	0.05	0.03	0.04	0.03
Small scale usage (per month)	60,19	117,9	94,65	145,56	-	66,194	-	194,46	-	-	7,25	-	35	-	-	175,36	4,09
Costs average	low	medium	medium	high	high	medium	high	high	medium	medium	low	high	low	high	medium	high	low

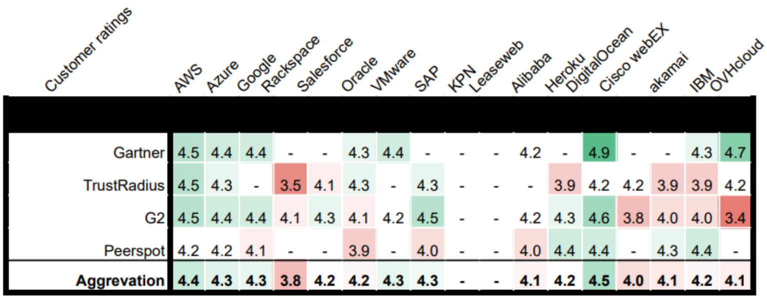
Figure 6.5: Decision model: Cost estimates

Customer ratings

The significance of customer perception garnered unanimous recognition among experts, while the literature emphasized the importance of customer support, as demonstrated in Table A.2. Customer ratings offer valuable real-world feedback from organizations that have already utilized the services of CSPs. These reviews provide firsthand insights into customers' actual experiences, aiding potential clients in comprehending the strengths and weaknesses of each provider.

By aggregating multiple reviews, organizations can access unbiased feedback from entities without affiliation to the CSPs, enabling a more impartial evaluation. The ratings highlight crucial aspects such as the CSP's service reliability, uptime, downtime, and responsiveness. Reliability holds particular significance for business-critical applications, and customer reviews play a vital role in assessing how well a provider adheres to its service level agreements. Furthermore, the level of customer support and responsiveness a CSP offers is a crucial consideration in cloud services. Customer ratings provide valuable insights into how effectively the CSP handles support requests, troubleshoots issues, and resolves problems promptly. For organizations operating within specific industries, customer ratings from companies with similar use cases become particularly valuable. Such insights can help identify CSPs with domain expertise that aligns closely with their unique needs and requirements. Incorporating customer ratings into the decision model ensures that the cloud selection process is not solely reliant on the CSPs' technical specifications or marketing materials. Instead, it entails learning from the real-world experiences of actual users. Organizations can make well-informed decisions that align precisely with their distinctive requirements and priorities by considering customer ratings alongside other critical factors such as cost, performance, security, and compliance. This comprehensive approach empowers organizations to choose the best CSP that optimally meets their cloud computing needs.

To obtain an unbiased estimate, independent customer rating websites were employed. Considering the potential bias associated with analyzing customer ratings from a single source, multiple websites were examined. Gartner, Trustradius, G2, and Peerspot were utilized within this decision model. The aggregated scores mentioned on these websites were used, and the corresponding links were provided to enable organizations to verify the underlying data. The ratings provided are visually represented using a color-coded system, where better ratings are depicted in green and worse ratings in red, as illustrated in Figure 6.6 by comparing the aggregated customer ratings, a comprehensive understanding of the quality of service provided can be obtained.



Customer ratings	AWS	Azure	Google	Rackspace	Salesforce	Oracle	VMware	SAP	KPN	Leaseweb	Alibaba	Heroku	DigitalOcean	Cisco webEX	akamai	IBM	OVHcloud
Gartner	4.5	4.4	4.4	-	-	4.3	4.4	-	-	-	4.2	-	4.9	-	-	4.3	4.7
TrustRadius	4.5	4.3	-	3.5	4.1	4.3	-	4.3	-	-	-	3.9	4.2	4.2	3.9	3.9	4.2
G2	4.5	4.4	4.4	4.1	4.3	4.1	4.2	4.5	-	-	4.2	4.3	4.6	3.8	4.0	4.0	3.4
Peerspot	4.2	4.2	4.1	-	-	3.9	-	4.0	-	-	4.0	4.4	4.4	-	4.3	4.4	-
Aggrevation	**4.4**	**4.3**	**4.3**	**3.8**	**4.2**	**4.2**	**4.3**	**4.3**	**-**	**-**	**4.1**	**4.2**	**4.5**	**4.0**	**4.1**	**4.2**	**4.1**

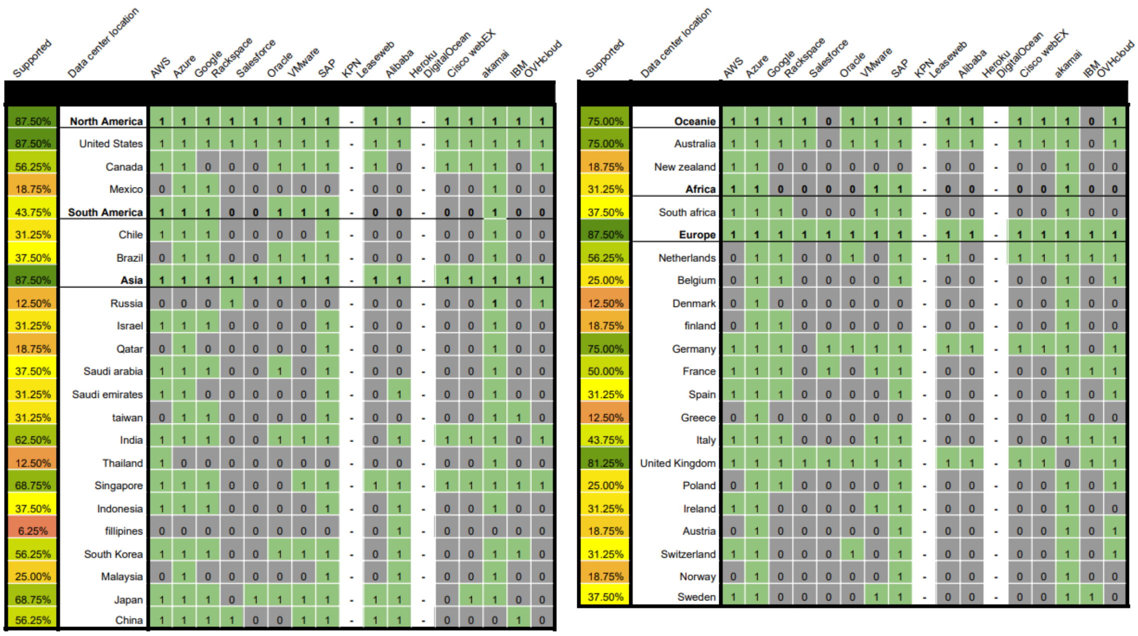
Figure 6.6: Decision model: customer ratings

Data center location

The topic of server location, although receiving relatively limited attention in the literature (see Table A.2), has been emphasized by experts due to its significance concerning compliance requirements and organizational policies.

The physical distance between the organization's users and the data center can notably impact latency, which refers to the time it takes for data to travel between the user and the server. A data center located in closer proximity generally results in lower latency, leading to enhanced application performance and improved user experience. Additionally, different countries and regions have varying data protection and privacy regulations. Hosting data in specific geographic locations might be necessary to adhere to these regulations. Thus, incorporating data center location into the decision model ensures that the chosen CSP aligns with the organization's compliance requirements. Furthermore, data center location is crucial in redundancy and disaster recovery strategies. Having data centers in different geographic regions can significantly enhance resilience against natural disasters or localized service disruptions, safeguarding critical data and applications. Incorporating data center location as a consideration in the decision model ensures that the selected CSP aligns with the organization's performance, compliance, and regulatory requirements. Overall, data center location represents a critical aspect of cloud selection that warrants careful consideration, particularly for organizations with specific geographic and regulatory prerequisites. By factoring in data center location when evaluating CSPs, organizations can make well-informed decisions that optimize performance, compliance adherence, and disaster recovery capabilities in their cloud adoption journey.

As a result, the decision model includes a comprehensive enumeration of all server locations for each CSP, where applicable. Within our decision model, we have employed a comprehensive approach by considering all server locations of the given providers to understand the variations thoroughly, utilizing boolean values for analysis purposes shown in Figure 6.7.



Supported	Data center location	AWS	Azure	Google	Rackspace	Salesforce	Oracle	VMware	SAP	KPN	Leaseweb	Alibaba	Heroku	DigitalOcean	Cisco webEX	akamai	IBM	OVHcloud
87.50%	**North America**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	-	**1**	**1**	-	**1**	**1**	**1**	**1**	**1**
87.50%	United States	1	1	1	1	1	1	1	1	-	1	1	-	1	1	1	1	1
56.25%	Canada	1	1	0	0	0	1	1	1	-	1	0	-	1	1	1	0	1
18.75%	Mexico	0	1	1	0	0	0	0	0	-	0	0	-	0	0	1	0	0
43.75%	**South America**	**1**	**1**	**1**	**0**	**0**	**1**	**1**	**1**	-	**0**	**0**	-	**0**	**0**	**1**	**0**	**0**
31.25%	Chile	1	1	1	0	0	0	0	1	-	0	0	-	0	0	1	0	0
37.50%	Brazil	0	1	1	0	0	1	1	1	-	0	0	-	0	0	1	0	0
87.50%	**Asia**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	-	**1**	**1**	-	**1**	**1**	**1**	**1**	**1**
12.50%	Russia	0	0	0	1	0	0	0	0	-	0	0	-	0	0	1	0	1
31.25%	Israel	1	1	1	0	0	0	0	1	-	0	0	-	0	0	1	0	0
18.75%	Qatar	0	1	0	0	0	0	0	1	-	0	0	-	0	0	1	0	0
37.50%	Saudi arabia	1	1	1	0	0	1	0	1	-	0	0	-	0	0	1	0	0
31.25%	Saudi emirates	1	1	0	0	0	0	0	1	-	0	1	-	0	0	1	0	0
31.25%	taiwan	0	1	1	0	0	0	0	1	-	0	0	-	0	0	1	1	0
62.50%	India	1	1	1	0	0	1	1	1	-	0	1	-	1	1	1	0	1
12.50%	Thailand	1	0	0	0	0	0	0	0	-	0	0	-	0	0	1	0	0
68.75%	Singapore	1	1	1	0	0	0	1	1	-	1	1	-	1	1	1	1	1
37.50%	Indonesia	1	1	1	0	0	0	0	1	-	0	1	-	0	0	1	0	0
6.25%	fillipines	0	0	0	0	0	0	0	0	-	0	1	-	0	0	0	0	0
56.25%	South Korea	1	1	1	0	0	1	1	1	-	0	1	-	0	0	1	1	0
25.00%	Malaysia	0	1	0	0	0	0	0	1	-	0	1	-	0	0	1	0	0
68.75%	Japan	1	1	1	0	1	1	1	1	-	1	1	-	0	1	1	0	0
56.25%	China	1	1	1	1	0	0	1	1	-	1	1	-	0	0	0	1	0

Supported	Data center location	AWS	Azure	Google	Rackspace	Salesforce	Oracle	VMware	SAP	KPN	Leaseweb	Alibaba	Heroku	DigitalOcean	Cisco webEX	akamai	IBM	OVHcloud
75.00%	**Oceanie**	**1**	**1**	**1**	**1**	**0**	**1**	**1**	**1**	-	**1**	**1**	-	**1**	**1**	**1**	**0**	**1**
75.00%	Australia	1	1	1	1	0	1	1	1	-	1	1	-	1	1	1	0	1
18.75%	New zealand	1	1	0	0	0	0	0	0	-	0	0	-	0	0	1	0	0
31.25%	**Africa**	**1**	**1**	**0**	**0**	**0**	**0**	**1**	**1**	-	**0**	**0**	-	**0**	**0**	**1**	**0**	**0**
37.50%	South africa	1	1	1	0	0	0	1	1	-	0	0	-	0	0	1	0	0
87.50%	**Europe**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	-	**1**	**1**	-	**1**	**1**	**1**	**1**	**1**
56.25%	Netherlands	0	1	1	0	0	1	0	1	-	1	0	-	1	1	1	1	1
25.00%	Belgium	0	1	1	0	0	0	0	1	-	0	0	-	0	0	1	0	1
12.50%	Denmark	0	1	0	0	0	0	0	0	-	0	0	-	0	0	1	0	0
18.75%	finland	0	1	1	0	0	0	0	0	-	0	0	-	0	0	1	0	0
75.00%	Germany	1	1	1	0	1	1	1	1	-	1	1	-	1	1	1	0	1
50.00%	France	1	1	1	0	1	0	1	1	-	0	0	-	0	0	1	1	1
31.25%	Spain	1	1	1	0	0	0	0	1	-	0	0	-	0	0	1	0	1
12.50%	Greece	0	1	0	0	0	0	0	0	-	0	0	-	0	0	1	0	0
43.75%	Italy	1	1	1	0	0	0	1	1	-	0	0	-	0	0	1	1	1
81.25%	United Kingdom	1	1	1	1	1	1	1	1	-	1	1	-	1	1	0	1	1
25.00%	Poland	0	1	1	0	0	0	0	1	-	0	0	-	0	0	1	0	1
31.25%	Ireland	1	1	0	0	0	0	1	1	-	0	0	-	0	0	1	0	0
18.75%	Austria	0	1	0	0	0	0	0	1	-	0	0	-	0	0	1	0	1
31.25%	Switzerland	1	1	0	0	0	1	0	1	-	0	0	-	0	0	1	0	1
18.75%	Norway	0	1	0	0	0	0	0	1	-	0	0	-	0	0	1	0	0
37.50%	Sweden	1	1	0	0	0	0	1	1	-	0	0	-	0	0	1	1	0

Figure 6.7: Decision model: Data center location

Compliance

Initially, compliance posed significant apprehensions during the early stages of cloud computing. However, as the industry evolved, cloud providers increasingly prioritized adherence to compliance standards. This significance of compliance is well-documented in the literature (see A.2) and supported by expert opinions. Organizations must conform to Various industries and regions with specific data protection and privacy regulations. Utilizing compliance as a comparison factor helps ensure that the selected CSP meets the legal and regulatory requirements, mitigating the risk of non-compliance penalties and legal issues.

Compliance standards often encompass security and privacy requirements. By selecting a CSP that complies with relevant standards, organizations can have confidence that their data will be adequately protected from unauthorized access, breaches, or leaks. Moreover, compliance standards often necessitate organizations to undergo audits and provide regular reports. A CSP with built-in compliance features can streamline the auditing process and alleviate the burden of compliance reporting for the organization. Furthermore, different industries have unique compliance requirements. For instance, healthcare organizations must adhere to the Health Insurance Portability and Accountability Act (HIPAA) regulations. Organizations can identify providers that cater to their particular needs by evaluating CSPs based on industry-specific compliance. Incorporating compliance into the cloud selection decision model ensures that organizations prioritize data protection, security, and adherence to legal and regulatory requirements. It aids in identifying a CSP that aligns with their industry-specific needs, risk tolerance, and long-term business objectives. Compliance considerations are vital in establishing a robust foundation for the organization's cloud strategy and data management practices. By addressing compliance requiOrganizations can bolster their cloud adoption journey payments in the decision-making process with heightened data security, enhanced regulatory compliance, and minimized legal risks.

The decision model lists a comprehensive compilation of global and financial compliance measures offered by the CSPs shown in Figure 6.8.

Supported	Compliance	AWS	Azure	Google	Rackspace	Salesforce	Oracle	VMware	SAP	KPN	Leaseweb	Alibaba	Heroku	DigitalOcean	Cisco webEX	akamai	IBM	OVHcloud
52.94%	GDPR	1	1	1	0	1	0	0	0	-	1	1	1	0	1	0	1	0
58.82%	CSA	1	1	1	0	1	1	0	1	-	0	1	0	1	0	0	1	1
17.65%	CIS benchmark	0	1	1	0	0	0	0	0	-	0	0	0	0	0	0	1	0
52.94%	C5	1	1	1	0	1	1	0	1	-	0	1	0	0	0	0	1	1
11.76%	GSMA SAS-SM	1	0	1	0	0	0	0	0	-	0	0	0	0	0	0	0	0
5.88%	HECVAT	0	0	1	0	0	0	0	0	-	0	0	0	0	0	0	0	0
17.65%	CyberGRX	1	0	1	0	1	0	0	0	-	0	0	0	0	0	0	0	0
5.88%	CyberVadis	1	0	0	0	0	0	0	0	-	0	0	0	0	0	0	0	0
47.06%	ISO 9001	1	1	1	1	0	1	0	1	-	0	1	0	0	0	0	1	0
11.76%	ISO 10012	0	0	0	0	0	0	0	1	-	0	1	0	0	0	0	0	0
5.88%	ISO 14001	0	0	0	1	0	0	0	0	-	0	0	0	0	0	0	0	0
29.41%	ISO 20000-1	1	1	0	0	0	1	0	1	-	0	1	0	0	0	0	0	0
35.29%	ISO 22301	1	1	1	0	0	0	0	1	-	0	1	0	0	0	0	1	0
5.88%	ISO 20243	0	0	0	0	0	0	0	0	-	0	0	0	0	0	0	1	0
88.24%	ISO 27001	1	1	1	1	1	1	0	1	-	1	1	1	1	1	1	1	1
5.88%	ISO 27110	0	0	1	0	0	0	0	0	-	0	0	0	0	0	0	0	0
47.06%	ISO 27701	1	1	1	0	0	1	0	0	-	0	1	0	0	0	1	1	1
64.71%	ISO 27017	1	1	1	0	1	1	0	1	-	0	1	1	0	0	1	1	1
64.71%	ISO 27018	1	1	1	0	1	1	0	1	-	0	1	1	0	0	1	1	1
5.88%	ISO 29151	0	0	0	0	0	0	0	0	-	0	1	0	0	0	0	0	0
5.88%	ISO 31000	0	0	0	0	0	0	0	0	-	0	0	0	0	0	0	1	0
5.88%	ISO 45001	0	0	0	1	0	0	0	0	-	0	0	0	0	0	0	0	0
11.76%	ISO 50001	0	0	1	0	0	0	0	1	-	0	0	0	0	0	0	0	0
23.53%	VPAT(WCAG)	1	1	1	0	1	0	0	0	-	0	0	0	0	0	0	0	0
70.59%	SOC 1	1	1	1	1	1	1	0	1	-	1	1	1	0	0	0	1	1
76.47%	SOC 2	1	1	1	1	1	1	0	1	-	0	1	1	1	0	1	1	1
64.71%	SOC 3	1	1	1	1	1	1	0	0	-	0	1	1	1	0	0	1	1
82.35%	PCI DSS	1	1	1	1	1	1	0	1	-	1	1	1	1	0	1	1	1
17.65%	PCI 3DS	0	1	1	0	0	0	0	0	-	0	1	0	0	0	0	0	0
5.88%	pinakes	1	0	0	0	0	0	0	0	-	0	0	0	0	0	0	0	0
11.76%	SWIPO data portability code of conduct	0	0	1	0	0	0	0	0	-	0	0	0	0	0	0	0	1
11.76%	EU cloud code of conduct	0	0	1	0	1	0	0	0	-	0	0	0	0	0	0	0	0
11.76%	EU standard contractual clauses	0	0	1	0	0	0	0	0	-	0	0	0	0	0	0	1	0
23.53%	EBA	0	1	1	0	0	0	0	0	-	0	0	0	0	0	0	1	1
5.88%	microfin (Germany)	0	0	1	0	0	0	0	0	-	0	0	0	0	0	0	0	0
11.76%	BaFin (germany)	0	0	1	0	0	0	0	0	-	0	0	0	0	0	0	1	0
17.65%	ACPR (france)	0	1	1	0	0	0	0	0	-	0	0	0	0	0	0	0	1
5.88%	AMF (france)	0	1	0	0	0	0	0	0	-	0	0	0	0	0	0	0	0
5.88%	Banco de espana	0	0	1	0	0	0	0	0	-	0	0	0	0	0	0	0	0
5.88%	Banco de portugal	0	0	1	0	0	0	0	0	-	0	0	0	0	0	0	0	0
5.88%	Bank of italy	0	0	1	0	0	0	0	0	-	0	0	0	0	0	0	0	0
5.88%	BSI critical infrastructure (KRITIS)	0	0	1	0	0	0	0	0	-	0	0	0	0	0	0	0	0
5.88%	BWG (austria)	0	0	1	0	0	0	0	0	-	0	0	0	0	0	0	0	0
5.88%	Central bank of ireland	0	0	1	0	0	0	0	0	-	0	0	0	0	0	0	0	0
5.88%	CSSF (luxembourgh)	0	0	1	0	0	0	0	0	-	0	0	0	0	0	0	0	0
11.76%	De Nederlandsche Bank	0	1	1	0	0	0	0	0	-	0	0	0	0	0	0	0	0
5.88%	AFM (netherlands)	0	1	0	0	0	0	0	0	-	0	0	0	0	0	0	0	0
5.88%	VAG (Austria)	0	0	1	0	0	0	0	0	-	0	0	0	0	0	0	0	0
5.88%	NBB and FSMA (belgium)	0	1	0	0	0	0	0	0	-	0	0	0	0	0	0	0	0
11.76%	KNF (poland)	0	1	1	0	0	0	0	0	-	0	0	0	0	0	0	0	0
17.65%	FINMA (Switzerland)	1	1	1	0	0	0	0	0	-	0	0	0	0	0	0	0	0
11.76%	FCA (UK)	0	1	1	0	0	0	0	0	-	0	0	0	0	0	0	0	0
5.88%	PRA (UK)	0	1	0	0	0	0	0	0	-	0	0	0	0	0	0	0	0

Figure 6.8: Decision model: Compliance

6.1.2 In-house knowledge

Experts were conclusive that the organization its current in-house knowledge should be used and supported by cloud providers to minimize migration challenges. To visualize the legacy supported, the decision model analyses the availability to bring your licenses and the supported operating systems, programming languages, and database systems. These features all contribute to the optimal use of in-house knowledge when transitioning towards a multi-cloud environment.

Bring your licenses

Adopting the Bring Your Own License (BYOL), approach empowers organizations to capitalize on their pre-existing software licenses. This practice yields substantial cost savings, as there is no necessity to repurchase licenses upon transitioning to the cloud. By evaluating CSPs based on their support for BYOL, organizations can identify providers that enable them to exploit the value of their current software assets fully.

Incorporating the consideration of BYOL in the cloud selection decision model allows organizations to assess which CSPs are the most flexible and compatible with their prevailing license agreements. By conducting such evaluations, organizations can seamlessly transfer their on-premises licenses to the cloud environment without incurring supplementary licensing fees or operational complexities. This heightened portability fosters greater agility in the cloud migration process and minimizes potential disruptions to core business operations. To conclude, including the BYOL model in the cloud selection decision model is paramount for organizations, as it effectively optimizes costs and safeguards their existing software investments.

Within the decision model, this feature denotes the extent to which a CSP permits the migration of existing licenses. It specifies the types of licenses that can be accommodated, shown in Figure 6.9 using boolean values.

Supported	Bring your own licenses	AWS	Azure	Google	Rackspace	Salesforce	Oracle	VMware	SAP	KPN	Leaseweb	Alibaba	Heroku	DigitalOcean	Cisco webEX	akamai	IBM	OVHcloud
29.41%	Windows 11	1	1	0	-	-	0	-	0	1	-	1	-	-	-	-	1	0
41.18%	Windows 10	1	1	1	-	-	1	-	0	1	-	1	-	-	-	-	1	0
23.53%	Windows 8	0	0	0	-	-	1	-	0	1	-	1	-	-	-	-	1	0
52.94%	Sql server	1	1	1	-	-	1	-	1	1	-	1	-	-	-	-	1	1
47.06%	windows server	1	1	1	-	-	0	-	1	1	-	1	-	-	-	-	1	1
35.29%	biztalk	1	1	1	-	-	0	-	0	1	-	1	-	-	-	-	1	0
41.18%	microsoft dynamics	1	1	1	-	-	1	-	0	1	-	1	-	-	-	-	1	0
41.18%	sharepoint	1	1	1	-	-	1	-	0	1	-	1	-	-	-	-	1	0
29.41%	SPLA	1	1	0	-	-	0	-	0	1	-	1	-	-	-	-	1	0
29.41%	skype	1	1	1	-	-	0	-	0	0	-	1	-	-	-	-	1	0
41.18%	exchange	1	1	1	-	-	1	-	0	1	-	1	-	-	-	-	1	0
41.18%	system center	1	1	1	-	-	1	-	0	1	-	1	-	-	-	-	1	0
35.29%	Remote Desktop Services	1	1	1	-	-	0	-	0	1	-	1	-	-	-	-	1	0
29.41%	MSDN	1	1	1	-	-	0	-	0	0	-	1	-	-	-	-	1	0
5.88%	team foundation server	0	1	0	-	-	0	-	0	0	-	0	-	-	-	-	0	0
5.88%	project server	0	1	0	-	-	0	-	0	0	-	0	-	-	-	-	0	0
5.88%	Ubuntu	0	0	1	-	-	0	-	0	0	-	0	-	-	-	-	0	0
11.76%	RHEL	0	0	1	-	-	0	-	0	0	-	0	-	-	-	-	1	0
35.29%	RHEL SAP	1	1	1	-	-	0	-	1	0	-	1	-	-	-	-	1	0
17.65%	SUSE	1	0	1	-	-	0	-	1	0	-	0	-	-	-	-	0	0
23.53%	oracle database	1	1	0	-	-	1	-	0	0	-	0	-	-	-	-	1	0
29.41%	IBM	1	1	1	-	-	0	-	0	0	-	0	-	-	-	-	1	1

Figure 6.9: Decision model: Bring your license

Operating systems supported

OS plays a foundational role in the computing environment, acting as the bedrock for managing all application programs within a computer system. These applications interact with the operating system by requesting services through a predefined API (Bigelow, 2023). Hence, the compatibility of the chosen CSP with the existing OS becomes crucial. Different applications and workloads may necessitate specific operating systems to function optimally. By considering the level of operating system support offered by various CSPs, organizations can ensure that their critical applications will run seamlessly without encountering compatibility issues. Moreover, if an organization is already utilizing a particular operating system in their on-premises environment, opting for a CSP that supports the same operating system can streamline the migration process. This, in turn, reduces the effort and time required to transfer workloads to the cloud. Additionally, the organization's IT team may possess expertise in managing and maintaining specific operating systems. Selecting a CSP that supports those operating systems enables the organization to leverage its existing skill set and minimizes the learning curve associated with effectively managing the cloud environment. Moreover, in a multicloud environment, the choice of operating system may influence the integration possibilities with other cloud services and tools. By meticulously evaluating CSPs based on operating system compatibility.

In conclusion, incorporating considerations of operating systems into the cloud selection decision model assumes critical importance for aligning cloud services with the organization's technical requirements and future growth plans. It facilitates informed decision-making, enabling organizations to identify the most suitable CSP that can provide optimal support for their specific workloads and applications.

The decision model enumerates the range of supported operating systems by the CSPs depicted in Figure 6.10 using boolean values.

Supported	Operating systems	AWS	Azure	Google	Rackspace	Salesforce	Oracle	VMware	SAP	KPN	Leaseweb	Alibaba	Heroku	DigitalOcean	Cisco webEX	akamai	IBM	OVHcloud
5.88%	**Container-optimized OS**	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11.76%	**Solaris**	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
11.76%	**IBM AIX**	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
11.76%	**Hp-UX**	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
94.12%	**Windows**	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1
11.76%	1709	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35.29%	10	0	1	1	0	1	0	1	1	0	0	0	0	0	1	0	0	0
23.53%	11	0	0	1	0	1	0	1	0	0	0	0	0	0	1	0	0	0
23.53%	8.1	0	0	1	0	1	0	1	1	0	0	0	0	0	0	0	0	0
17.65%	8	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	1	0
23.53%	7	0	0	1	0	1	0	0	1	0	0	0	0	0	0	0	1	0
11.76%	2003	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0
5.88%	2004	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
47.06%	2008	1	1	1	1	0	0	0	0	0	0	1	0	0	1	1	1	0
70.59%	2012	1	1	1	1	0	1	1	1	1	1	1	0	0	0	1	1	0
5.88%	2014	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
70.59%	2016	1	1	1	1	0	1	1	1	1	1	1	0	0	0	1	0	1
5.88%	2017	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
41.18%	2019	1	1	1	0	0	0	1	0	0	1	1	0	0	0	0	0	1
35.29%	2022	1	1	1	0	0	0	1	0	0	1	1	0	0	0	0	0	0

Supported	Operating systems	AWS	Azure	Google	Rackspace	Salesforce	Oracle	VMware	SAP	KPN	Leaseweb	Alibaba	Heroku	DigitalOcean	Cisco webEX	akamai	IBM	OVHcloud
88.24%	**Linux**	1	1	1	1	0	1	1	1	0	1	1	1	1	1	1	1	1
23.53%	Oracle linux	1	1	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0
64.71%	d Hat Enterprise Linux (RHEL)	1	1	1	0	0	1	1	1	1	0	1	0	0	1	1	1	0
11.76%	openSUSE	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0
52.94%	SUSE Linux Enterprise Server	1	1	1	0	0	1	1	1	0	0	1	0	0	0	1	1	0
5.88%	Clearlinux	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29.41%	VMware esx	0	0	0	0	0	1	1	0	0	1	0	0	0	0	0	1	1
5.88%	Arch linux	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
5.88%	asianux	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
11.76%	Fedora CoreOS	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0
29.41%	Fedora	0	0	0	1	0	0	1	0	0	0	1	0	1	1	0	0	0
76.47%	Ubuntu	1	1	1	1	0	1	1	1	1	0	0	1	1	0	1	1	1
5.88%	linux mint	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
5.88%	Fortinet	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
5.88%	anolis OS	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
5.88%	FreeBSD	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
5.88%	CoreOS	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
23.53%	Rocky linux	1	0	1	0	0	0	0	0	0	0	1	0	1	0	0	0	0
11.76%	Alma linux	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0
5.88%	kali	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
52.94%	CentOS	1	1	0	1	0	0	1	0	1	0	1	0	1	0	1	0	1
11.76%	centOS Stream	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
5.88%	Bottlerocket	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
64.71%	Debian	1	1	1	1	0	0	1	0	0	0	1	1	1	1	1	0	1
23.53%	**MacOS**	1	0	0	0	1	0	0	0	0	0	0	1	0	1	0	0	0
11.76%	**Raspberry pi OS**	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0

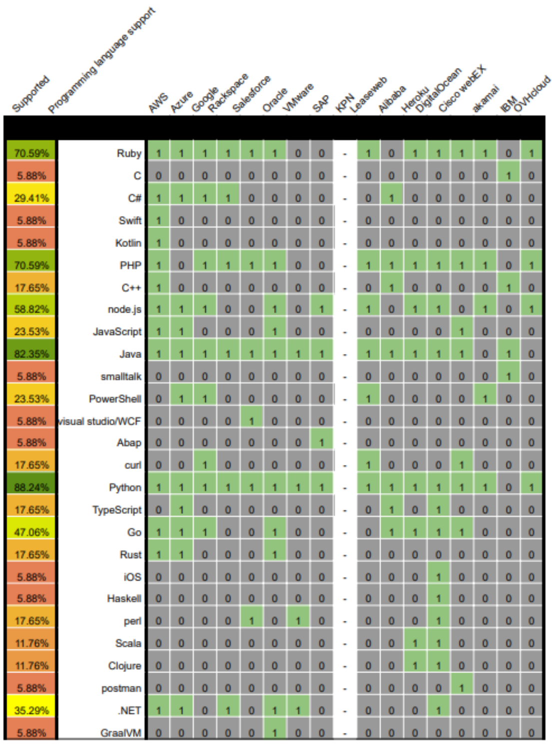
Figure 6.10: Decision model: Operating systems

Programming language supported

CSPs may offer varying degrees of support for different programming languages. Thoroughly considering the availability of specific programming languages within a CSP becomes imperative to ensure that developers can effectively build and deploy applications using their preferred language. It is worth noting that certain applications may be developed using specific programming languages, and not all CSPs may provide support for all languages. Furthermore, certain programming languages boast rich ecosystems of third-party libraries, frameworks, and tools that enhance development capabilities and overall performance. By carefully evaluating CSPs based on their offerings of programming languages, organizations can make informed decisions to select a provider that aligns Organizations can ensure seamless integration across their cloud infrastructure seamlessly with their application development needs. Additionally, some organizations may have legacy applications developed using specific programming languages. Selecting a CSP that extends support to these languages facilitates the smooth migration of such legacy systems to the cloud without incurring significant redevelopment efforts. For organizations operating in a multi-cloud environment, the choice of programming language may also influence the integration possibilities with other cloud services and tools. Hence, by conducting thorough evaluations of CSPs based on their compatibility with the organization's preferred programming languages, seamless integration across the cloud infrastructure can be ensured.

In conclusion, incorporating considerations of programming languages into the cloud selection decision model is crucial in ensuring that the chosen CSP precisely aligns with the organization's unique application development requirements, the skillset of its developers, performance demands, and long-term strategic objectives.

The decision model comprehensively outlines the array of supported programming languages offered by the CSPs shown in Figure 6.11 using boolean values.



Supported	Programming language support	AWS	Azure	Google	Rackspace	Salesforce	Oracle	VMware	SAP	KPN	Leaseweb	Alibaba	Heroku	DigitalOcean	Cisco webEX	akamai	IBM	OVHcloud
70.59%	Ruby	1	1	1	1	1	1	0	0	-	1	0	1	1	1	1	0	1
5.88%	C	0	0	0	0	0	0	0	0	-	0	0	0	0	0	0	1	0
29.41%	C#	1	1	1	1	0	0	0	0	-	0	1	0	0	0	0	0	0
5.88%	Swift	1	0	0	0	0	0	0	0	-	0	0	0	0	0	0	0	0
5.88%	Kotlin	1	0	0	0	0	0	0	0	-	0	0	0	0	0	0	0	0
70.59%	PHP	1	0	1	1	1	1	0	0	-	1	1	1	1	1	1	0	1
17.65%	C++	1	0	0	0	0	0	0	0	-	0	1	0	0	0	0	1	0
58.82%	node.js	1	1	1	0	0	1	0	1	-	1	0	1	1	0	1	0	1
23.53%	JavaScript	1	1	0	0	0	1	0	0	-	0	0	0	0	1	0	0	0
82.35%	Java	1	1	1	1	1	1	1	1	-	1	1	1	1	1	0	1	0
5.88%	smalltalk	0	0	0	0	0	0	0	0	-	0	0	0	0	0	0	1	0
23.53%	PowerShell	0	1	1	0	0	0	0	0	-	1	0	0	0	0	1	0	0
5.88%	visual studio/WCF	0	0	0	0	1	0	0	0	-	0	0	0	0	0	0	0	0
5.88%	Abap	0	0	0	0	0	0	0	1	-	0	0	0	0	0	0	0	0
17.65%	curl	0	0	1	0	0	0	0	0	-	1	0	0	0	1	0	0	0
88.24%	Python	1	1	1	1	1	1	1	1	-	1	1	1	1	1	1	0	1
17.65%	TypeScript	0	1	0	0	0	0	0	0	-	0	1	0	1	0	0	0	0
47.06%	Go	1	1	1	0	0	1	0	0	-	0	1	1	1	1	0	0	0
17.65%	Rust	1	1	0	0	0	1	0	0	-	0	0	0	0	0	0	0	0
5.88%	iOS	0	0	0	0	0	0	0	0	-	0	0	0	1	0	0	0	0
5.88%	Haskell	0	0	0	0	0	0	0	0	-	0	0	0	1	0	0	0	0
17.65%	perl	0	0	0	0	1	0	1	0	-	0	0	0	1	0	0	0	0
11.76%	Scala	0	0	0	0	0	0	0	0	-	0	0	1	1	0	0	0	0
11.76%	Clojure	0	0	0	0	0	0	0	0	-	0	0	1	1	0	0	0	0
5.88%	postman	0	0	0	0	0	0	0	0	-	0	0	0	0	1	0	0	0
35.29%	.NET	1	1	0	1	0	1	1	0	-	0	0	0	1	0	0	0	0
5.88%	GraalVM	0	0	0	0	0	1	0	0	-	0	0	0	0	0	0	0	0

Figure 6.11: Decision model: programming language supported

Database systems supported

Diverse CSPs present an array of database systems, each characterized by distinct features and capabilities (altexsoft, 2023). The evaluation of such database offerings assumes paramount importance for organizations aiming to select a CSP that seamlessly aligns with their data management requirements, encompassing considerations such as data volume, scalability, and performance. In the context of applications, particular database systems often serve as the bedrock for data storage and retrieval processes. Consequently, the selection of an appropriate database system significantly influences application performance, particularly in the context of data-intensive applications. Therefore, ensuring that a chosen CSP offers support for the requisite database system becomes a critical aspect for facilitating smooth integration, compatibility, and optimal performance alongside existing applications. Furthermore, database systems may come equipped with built-in management tools and features for backups, monitoring, and scaling tasks. By assessing CSPs based on the availability and capabilities of these management tools, organizations can streamline their database administration tasks, leading to enhanced operational efficiency. Additionally, different database systems demonstrate proficiency in managing specific data models, such as relational, NoSQL, graph, or time-series data models. Consequently, opting for a CSP that supports the most suitable data model aligning with the organization's data types can yield data storage and retrieval efficiency improvements.

In conclusion, incorporating considerations of database systems into the cloud selection decision model holds undeniable significance for organizations seeking to ensure that their chosen CSP adequately fulfills their data management and performance requirements. Through a comprehensive evaluation of CSPs based on their respective database offerings, organizations can make well-informed decisions and identify a provider that best fits their specific data storage, retrieval, and overall management needs.

In Figure 6.12, the decision model comprehensively presents the range of DBMS types supported by the CSPs using boolean values.

Supported	Databases (out of box)	AWS	Azure	Google	Rackspace	Salesforce	Oracle	VMware	SAP	KPN	Leaseweb	Alibaba	Heroku	DigitalOcean	Cisco webEX	akamai	IBM	OVHcloud
	Databases (out of box)																	
52.94%	mysql	1	1	1	1	0	1	0	0	-	0	1	0	1	-	1	0	1
52.94%	SQL Server	1	1	1	1	0	0	1	1	-	1	1	0	0	-	0	1	0
11.76%	IBM DB2	0	0	0	0	0	0	0	1	-	0	0	0	0	-	0	1	0
47.06%	oracle	1	0	1	1	1	1	1	1	-	0	0	0	0	-	0	1	0
35.29%	Redis	0	1	1	0	0	0	0	0	-	0	1	1	1	-	0	0	1
52.94%	Postgres	1	1	1	1	0	0	0	0	-	0	1	1	1	-	1	0	1
11.76%	Apache Kafka	0	0	0	0	0	0	0	0	-	0	0	1	0	-	0	0	1
23.53%	nosql	0	0	1	1	0	0	0	0	-	0	1	0	0	-	0	0	1
11.76%	apache cassandra	0	1	0	0	0	0	0	0	-	0	0	0	0	-	0	0	1
23.53%	mongodb	0	0	1	0	0	0	0	0	-	0	1	0	1	-	0	0	1
11.76%	mariadb	1	1	0	0	0	0	0	0	-	0	0	0	0	-	0	0	0

Figure 6.12: Decision model: Database systems support

6.1.3 Combination enablement

As mentioned in literature in 4.7.3, the establishment of a multi-cloud environment needs the fulfillment of various requirements. Moreover, experts all affirm the significance of effective integration and communication mechanisms among CSPs. To align with the established decision model, the investigation examines the following features: API methods supported, and container orchestration.

API supported

Integration has garnered significant attention from experts, focusing on interoperability and managing complexity, as evidenced in the literature (see table A.2). While acknowledging the programmability of various cloud elements, experts also caution that complexity may arise in specific scenarios. Central to enabling integration and interoperability between different cloud services and applications are Application Programming Interfaces (APIs). APIs are critical in impacting cloud services' scalability and performance. Efficient APIs facilitate quick response times and smooth scaling of resources, ensuring organizations can effectively handle varying workloads. Therefore, evaluating API support among CSPs becomes crucial for organizations to ensure that the selected providers offer efficient APIs compatible with their existing systems and applications. Moreover, API support holds significance in enabling a multi-cloud approach, as it allows organizations to build applications and services independent of any single provider, thereby avoiding vendor lock-in. Conversely, inadequate API support or restrictive APIs in a CSP can impede the organization's ability to switch or scale services easily.

By incorporating API support among CSPs into the multi-cloud selection decision model, organizations can ensure that the chosen providers align with their integration and performance requirements. Robust API support enhances the organization's ability to seamlessly work with multiple cloud environments, leading to a more flexible, efficient, and agile cloud strategy. As a result, the organization can adapt to dynamic business needs and capitalize on the benefits of a multi-cloud approach while mitigating potential challenges associated with integration and interoperability.

All supported API methods by the CSPs are shown in Figure 6.13. These API methods are valuable tools for facilitating seamless integration and reducing complexities within the multi-cloud environment.

Supported	API supported	AWS	Azure	Google	Rackspace	Salesforce	Oracle	VMware	SAP	KPN	Leaseweb	Alibaba	Heroku	DigitalOcean	Cisco webEX	akamai	IBM	OVHcloud
100.00%	HTTPs API	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
100.00%	REST API	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
82.35%	Websocket API	1	1	1	0	1	1	1	1	0	0	1	1	1	1	1	1	1
94.12%	OpenAPI	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1
88.24%	SOAP API	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1
82.35%	GraphQl API	1	1	1	0	1	1	1	1	0	0	1	1	1	1	1	1	1
82.35%	gRPC	1	1	1	0	1	1	1	1	0	0	1	1	1	1	1	1	1
64.71%	Bulk API	1	1	1	0	1	1	1	1	0	0	1	1	0	1	0	1	0
70.59%	Pub/Sub API	1	1	1	1	1	1	1	1	0	0	1	1	0	1	0	1	0
64.71%	ODATA	1	1	1	1	1	1	1	1	0	0	1	1	0	0	0	1	0
88.24%	CORS	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1
58.82%	Apigee API	1	1	1	0	1	1	0	1	1	0	1	0	1	0	1	0	0
100.00%	OAuth	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Figure 6.13: Decision model: API supported

Container orchestration

As discussed in Section 4.7.3, managing a multi-cloud system can be effectively facilitated through containerization; containerization entails encapsulating software code and the necessary operating system (OS) libraries and dependencies into a container, which can be executed consistently across diverse infrastructure environments, as affirmed by IBM (IBM, 2023a). Organizations can ensure consistent deployment and management of applications across different cloud environments by employing container orchestration. Efficient container orchestration enables optimal resource utilization by automatically scaling applications based on demand. It also facilitates automatic load balancing, ensuring equitable distribution of workloads across the cloud infrastructure, yielding cost savings and improved performance through more effective resource allocation. Moreover, container orchestration systems, exemplified by Kubernetes, possess an extensive ecosystem of tools and integrations, empowering organizations to leverage these integrations to enhance various aspects of their cloud infrastructure, including logging, monitoring, security, and networking.

Organizations can ascertain the feasibility of quickly migrating or scaling their applications between clouds without significant modifications by assessing container orchestration support among CSPs. As containerization has become a standard practice in modern application development, selecting a CSP with robust container orchestration capabilities is paramount to ensure readiness for future technological advancements and industry trends. Integrating container orchestration capabilities into the multi-cloud selection decision model enables organizations to identify CSPs that offer comprehensive and feature-rich container management solutions. Moreover, strong container orchestration support augments the organization's ability to embrace cloud-native technologies, fostering competitiveness in a swiftly evolving cloud landscape.

To see compatibility and availability with containers, the decision model encompasses multiple methods and their support towards CSPs in Figure 6.14.

Supported	Container orchestration	AWS	Azure	Google	Rackspace	Salesforce	Oracle	VMware	SAP	KPN	Leaseweb	Alibaba	Heroku	DigitalOcean	Cisco webEX	akamai	IBM	OVHcloud
64.71%	kubernetes	1	1	1	1	-	1	1	-	-	-	1	1	1	-	-	1	1
64.71%	Docker Swarm	1	1	1	1	-	1	1	-	-	-	1	1	1	-	-	1	1
58.82%	openshift	1	1	1	1	-	1	1	-	-	-	1	0	1	-	-	1	1
58.82%	cloud foundry	1	1	1	1	-	1	1	-	-	-	1	0	1	-	-	1	1
58.82%	Apache Mesos	1	1	1	1	-	1	1	-	-	-	1	0	1	-	-	1	1
58.82%	nomad	1	1	1	1	-	1	1	-	-	-	1	0	1	-	-	1	1
35.29%	kontena	1	1	1	0	-	0	0	-	-	-	0	0	1	-	-	1	1

Figure 6.14: Decision model: container orchestration

6.2 CSP alternatives

The decision model encompasses a comprehensive selection of 17 CSPs that have been identified either through relevant literature or cited as significant players in the cloud computing market by industry experts. Each of these CSPs possesses a USP, distinguishing them from one another and catering to specific demands within the market. This section provides a detailed enumeration and description of these 17 cloud providers, shedding light on their individual characteristics and offerings.

1. **Amazon Web Services**: AWS is one of the largest and most popular cloud service providers, offering various services such as computing power, storage options, and databases. Its unique selling point lies in its extensive global network of data centers, high reliability, and scalability. AWS provides on-demand services, enabling businesses to pay only for the resources they use, making it cost-efficient.

2. **Microsoft Azure**: Azure is Microsoft's cloud computing platform, providing a wide range of services, including virtual machines, databases, and AI capabilities. Its unique selling point is seamless integration with Microsoft's ecosystem, allowing businesses already using Microsoft technologies to transition to the cloud smoothly. Azure also offers robust hybrid cloud solutions, enabling organizations to combine on-premises and cloud environments.

3. **Google Cloud Platform**: GCP offers cloud services, including data storage, machine learning, and networking. Its unique selling point is its strong focus on data analytics and machine learning capabilities. GCP's data processing and AI tools make it attractive for organizations seeking advanced data-driven insights.

4. **Rackspace**: Rackspace provides managed cloud services, providing support and expertise to businesses migrating to the cloud. Its unique selling point is its driven services

approach, offering hands-on support to help organizations with cloud adoption and management.

5. **Salesforce**: Salesforce is a cloud-based customer relationship management (CRM) platform. Its unique selling point is its specialization in CRM solutions, empowering businesses to efficiently manage customer data, sales, marketing, and service processes.

6. **Oracle Cloud**: Oracle Cloud offers a comprehensive suite of cloud services, including databases, applications, and infrastructure. Its unique selling point is its focus on enterprise-grade database solutions, which are well-suited for businesses dealing with large-scale data management.

7. **VMware Cloud**: VMware Cloud provides a platform for organizations to run their virtualized workloads in the cloud. Its unique selling point is its ability to seamlessly integrate with existing VMware infrastructure, offering a consistent and familiar environment for businesses with virtualization expertise.

8. **SAP Cloud Platform**: SAP Cloud Platform offers various services for developing, deploying, and managing cloud applications. Its unique selling point is its specialization in enterprise-grade applications and integration with SAP's business software solutions.

9. **KPN**: KPN is a Dutch CSP offering various cloud services tailored to businesses in the Netherlands. Its unique selling point is its local presence, providing data sovereignty and localized support to Dutch organizations.

10. **Leaseweb**: Leaseweb is a global CSP providing various cloud services, including dedicated servers and private cloud options. Its unique selling point is its flexibility in customizing solutions to meet specific business needs.

11. **Alibaba Cloud**: Alibaba Cloud is a leading CSP in Asia, offering a broad range of cloud services, including big data analytics and AI. Its unique selling point is its strong presence in the Asian market, providing services tailored to the region's specific requirements.

12. **Heroku**: Heroku is a cloud platform for building, deploying, and managing applications. Its unique selling point is its focus on simplifying the development process, enabling developers to focus on building features rather than managing infrastructure.

13. **DigitalOcean**: DigitalOcean is known for its simplicity and developer-friendly cloud platform. Its unique selling point is its ease of use, making it an attractive choice for developers and startups.

14. **Cisco WebEx**: Cisco WebEx is a collaboration platform offering web conferencing, online meetings, and video conferencing. Its unique selling point is its focus on seamless communication and collaboration for businesses and remote teams.

15. **Akamai**: Akamai provides a content delivery network (CDN) service to optimize web content delivery. Its unique selling point is its global network of servers, enhancing website performance and security.

16. **IBM Cloud**: IBM Cloud offers many cloud services, including AI, data analytics, and blockchain solutions. Its unique selling point is its focus on enterprise-grade solutions and expertise in hybrid cloud deployments.

17. **OVHcloud**: OVHcloud is a European CSP providing various cloud services, including private and public cloud options. Its unique selling point is its strong emphasis on data privacy and security, adhering to European data protection regulations.

Each CSP has strengths and specializations, making them suitable for business needs and requirements. Organizations should carefully assess their specific needs and consider the unique selling points of each CSP to make an informed decision about cloud adoption.

Organizations are encouraged to utilize this decision model and acquire data on the features mentioned in this chapter with a list of relevant providers. While the suggested providers for this decision model can serve as a starting point, organizations may also consider other providers based on their specific requirements and unique selling propositions (USPs). For instance, if an organization prioritizes robust access management or security services, researching USPs in reports such as Gartner can help identify suitable providers to include in the decision model for assessing compatibility.

6.3 Feasible combination mapping

In order to ensure the feasibility of a multi-cloud solution, it is crucial to examine strategic partnerships and use cases. This examination serves to assess the compatibility and combinability of different CSPs. Strategic partnerships between CSPs can facilitate seamless integration and collaboration, enabling enhanced interoperability within a multi-cloud environment. By considering documented use cases, organizations can gain insights into real-world scenarios where CSP combinations have been successfully implemented, further confirming the feasibility of combining specific CSPs.

By analyzing strategic partnerships and use cases, organizations can make informed decisions regarding the selection of CSPs that are capable of effectively working together in a multi-cloud setup. This evaluation ensures that the chosen CSPs have established synergistic relationships and proven compatibility, which minimizes potential integration challenges and enhances the overall feasibility of the multi-cloud solution.

6.3.1 Partners

During the evaluation of various CSPs, it came to light that certain strategic partnerships exist between them. These collaborative alliances have the potential to facilitate improved integration and collaboration among CSPs, leading to enhanced interoperability and seamless interactions within a multi-cloud environment. Such partnerships between CSPs often result in better service interoperability and integration. This, in turn, enables smoother transfer and management of data and applications across multiple cloud platforms, ultimately enhancing efficiency and reducing complexity for organizations. Furthermore, partnership CSPs may offer joint service or bundled packages, presenting unique and cost-effective solutions to organizations. These collaborations might also ensure that critical services are redundantly available across multiple clouds. By considering and leveraging such partnerships, an organization can access specialized services or discounts that may not be available through a single CSP. Incorporating existing partnerships among CSPs into the decision-making process of multi-cloud selection allows organizations to identify potential synergies and technical advantages arising from these collaborative efforts. Additionally, evaluating the extent and strength of partnerships between CSPs can serve as a factor in assessing the long-term viability and stability of a multi-cloud strategy.

In conclusion, considering the presence of strategic partnerships among CSPs is paramount when selecting a multi-cloud environment. Such considerations enable organizations to identify potential benefits arising from collaborative initiatives and gauge their multi-cloud approach's long-term sustainability and effectiveness.

The specific partnerships or collaborations established between CSPs are documented and presented within the decision model, shown in Figure 6.15. This information provides valuable insights into the potential benefits and synergies of leveraging these strategic partnerships when selecting and integrating CSPs within the multi-cloud architecture.

Partners	AWS	Azure	Google	Rackspace	Salesforce	Oracle	VMware	SAP	KPN	Leaseweb	Alibaba	Heroku	DigitalOcean	Cisco webEX	akamai	IBM	OVHcloud
AWS	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Azure	1	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Google	1	1	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Rackspace	1	1	1	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Salesforce	1	1	1	1	x	x	x	x	x	x	x	x	x	x	x	x	x
Oracle	1	1	1	1	1	x	x	x	x	x	x	x	x	x	x	x	x
VMware	1	1	1	1	1	1	x	x	x	x	x	x	x	x	x	x	x
SAP	1	1	1	1	1	1	1	x	x	x	x	x	x	x	x	x	x
KPN	1	1	0	0	1	1	1	1	x	x	x	x	x	x	x	x	x
Leaseweb	1	1	1	1	0	0	1	1	0	x	x	x	x	x	x	x	x
Alibaba	0	0	0	1	1	1	1	1	0	0	x	x	x	x	x	x	x
Heroku	1	0	1	1	1	1	1	0	0	0	1	x	x	x	x	x	x
CloudFoundry	0	1	1	1	0	0	1	1	0	0	1	0	x	x	x	x	x
Cisco webEX	1	1	1	1	1	1	1	1	1	0	1	1	0	x	x	x	x
akamai	0	1	1	1	1	1	1	1	0	0	1	0	0	1	x	x	x
IBM	1	1	1	0	1	1	1	1	1	1	1	1	0	1	1	x	x
OVHcloud	0	1	1	0	0	0	1	1	0	0	0	0	0	0	0	1	x

Figure 6.15: Decision model: Partners

6.3.2 Combination use cases

To ensure the efficacy of strategic partnerships between CSPs, the decision model incorporates industry examples or documentation demonstrating the practical implementation of CSP combinations. By examining existing use cases, organizations can assess if a CSP has prior experience serving businesses or industries similar to theirs. Analyzing how other organizations have successfully employed a particular CSP for specific use cases provides valuable insights into its relevance and suitability for meeting the organization's unique needs. Understanding how other organizations have integrated the services of a CSP into their existing infrastructure and applications helps evaluate the ease of integration and interoperability with the organization's systems. This assessment ensures that the chosen CSP seamlessly aligns with the organization's technological landscape. Furthermore, presenting concrete examples of successful use cases involving a particular CSP can instill confidence among stakeholders and decision-makers, facilitating buy-in for the multi-cloud strategy.

By incorporating existing use cases among CSPs into the multi-cloud selection decision model, organizations are empowered to make well-informed decisions based on the real-world experiences of other users. This approach enhances the overall decision-making process, leading to a more effective and successful implementation of the multi-cloud strategy.

The industry examples are shown in Figure 6.16. These resources serve as valuable references for organizations seeking guidance on effectively integrating and combining different CSPs within a multi-cloud environment. By providing concrete examples and documented practices, the decision model assists organizations in making informed decisions and implementing successful combinations of CSPs that align with their specific business requirements and objectives.

Combinations examples	AWS	Azure	Google	Rackspace	Salesforce	Oracle	VMware	SAP	KPN	Leaseweb	Alibaba	Heroku	DigitalOcean	Cisco webEX	akamai	IBM	OVHcloud
AWS	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Azure	1	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Google	1	0	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Rackspace	0	1	1	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Salesforce	1	1	1	1	x	x	x	x	x	x	x	x	x	x	x	x	x
Oracle	1	1	1	1	1	x	x	x	x	x	x	x	x	x	x	x	x
VMware	1	1	1	1	0	1	x	x	x	x	x	x	x	x	x	x	x
SAP	1	1	1	1	1	1	1	x	x	x	x	x	x	x	x	x	x
KPN	1	1	0	0	0	0	1	1	x	x	x	x	x	x	x	x	x
Leaseweb	1	1	1	0	1	0	0	1	0	x	x	x	x	x	x	x	x
Alibaba	0	1	1	0	1	1	1	1	0	0	x	x	x	x	x	x	x
Heroku	1	0	1	0	1	1	0	0	0	0	0	x	x	x	x	x	x
DigitalOcean	1	1	1	0	0	0	0	0	0	0	1	0	x	x	x	x	x
Cisco webEX	1	1	1	1	1	1	0	1	1	0	0	0	0	x	x	x	x
akamai	0	1	1	1	1	1	1	0	0	0	0	0	0	1	x	x	x
IBM	1	1	0	0	1	1	1	1	0	0	1	0	0	1	1	x	x
OVH	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	x

Figure 6.16: Decision model: Combination use cases

6.4 Data acquisition

The data about the features examined in this study was acquired through online documentation. The selection of providers was determined based on information obtained from literature and expert interviews, incorporating both existing providers mentioned in the literature and additional providers suggested by the domain experts. It should be noted that the data presented in the figures concerning the decision model's features will inevitably become outdated over time.

To effectively utilize the fundamental aspects of this decision model, organizations seeking to identify a compatible set of CSPs for their multi-cloud environment should employ web scraping techniques to gather up-to-date data from online documentation. The selection of CSPs within the decision model should be guided by their popularity, past experiences with the CSP, or the USP offered by the CSP in question. By incorporating these considerations, organizations can enhance the accuracy and relevance of their shortlist of CSPs within the multi-cloud environment given by our decision model.

6.5 Calculation

In this research, the Weighted Sum Model (WSM) was selected as the preferred calculation method, despite the availability of various MCDM models, as presented in Table A.4. The decision to use the WSM over a more intricate MCDM approach for the MOSCOW method was based on its appropriateness for scenarios where the decision problem exhibits relative simplicity and lacks strong interactions or trade-offs among the criteria. The WSM is a straightforward aggregation method that expedites the computation of overall scores for alternatives by incorporating weighted criteria.

The MOSCOW method, widely employed in project management and requirements engineering, entails classifying requirements into four priority classes: Must have, Should have, Could have, and Won't have. A scoring system is employed to establish priorities among these requirements, wherein numerical values are assigned to each category. The simplicity and ease of implementation render the WSM a practical choice. The assignment of weights to each category (Must have, Should have, Could have) based on their relative importance can be readily accomplished without necessitating complex calculations. Moreover, when the number of criteria remains limited, the decision problem's complexity is reduced, further justifying the utilization of the WSM. In the context of the MOSCOW method, where requirements are independently assessed and categorized into priority classes without explicit interdependencies, the WSM emerges as a suitable method for specific aggregation. Its ability to accommodate independent criteria aligns well with the nature of the MOSCOW prioritization technique.

Nevertheless, it is crucial to acknowledge that the suitability of the WSM for MOSCOW prioritization hinges on the specific context and complexity of the decision problem. In scenarios involving a larger number of criteria, intricate interactions, or significant trade-offs between requirements, a more robust MCDM approach such as AHP or TOPSIS might prove more appropriate. Nonetheless, the WSM emerged as the most suitable choice for the MOSCOW method in the current context, effectively addressing the research objectives.

Chapter 7

Empirical evidence

Three case studies were undertaken to assess the decision model's validity. The selection criteria for these case studies necessitated the presence of a multi-cloud environment, coupled with a focus on serving a specific industry, as depicted in Figure 7.2. As discussed in Chapter 6, the MoSCoW technique was employed for feature prioritization. The requirements identified through the case studies are presented in Figure 7.1, showcasing the distribution of must-haves, could-haves, should-haves, and won't-haves. Moreover, at the end of the chapter, Figure 7.2 provides a visual representation of the quantities of these requirements and the existing and proposed solutions for the corresponding multi-cloud environments. Subsequent sections of this chapter will delve into a comprehensive examination of these case studies.

7.1 Case study 1: Software producer

The software producer is a multinational software company specializing in 3D design, modeling, simulation, and product lifecycle management solutions. Founded in 1981, the company is headquartered in France and has a global presence with offices and operations in various countries.

The company's flagship product is "CATIA," which stands for Computer-Aided Three-Dimensional Interactive Application. CATIA is a leading 3D design and modeling software in various industries, including aerospace, automotive, industrial equipment, and consumer goods. It enables engineers and designers to create, simulate, and analyze complex 3D models of products and systems, facilitating the entire product development process from concept to manufacturing.

Companies across industries widely use the software producer' solutions to enhance innovation, collaboration, and efficiency in product development. Their SaaS tools play a crucial role in accelerating the design and manufacturing processes, reducing time-to-market, and ensuring the overall quality of products. As a result, the software producer has become a significant player; with a workforce exceeding 20,000 employees, the company operates globally, catering to 192 countries and maintaining regional offices in diverse geographical areas.

7.1.1 Current situation

The software producer, a prominent multinational software company, has adopted an intricate and sophisticated multi-cloud architecture, combining in-house solutions with integrating leading cloud service providers. Central to their multi-cloud strategy is their proprietary infrastructure provider, Outskill, which fulfills a crucial role in hosting essential SaaS products

Requirement	Case study 1	Case study 2	Case study 3	ID
Data management	m	m	m	R01
Analytics and BI	m	m	m	R02
Database	m	m	m	R03
Virtual machines	m	m	m	R04
Data lakes	m	m	m	R05
Disaster recovery	m	m	m	R06
Infrastructure	m	m	m	R07
virtual desktop	m	m	m	R08
Load balancers	m	m	m	R09
Domain name systems (DNS)	m	m	m	R10
Developer tools	m	m	m	R11
Commandline interface (CLI)	m	m	m	R12
Management & governance	m	m	m	R13
cost management	m	m	m	R14
Monitoring	m	m	m	R15
Platform building	m	m	m	R16
Migration and transfer	m	m	m	R17
Data migration	m	m	m	R18
Application integration	m	m	m	R19
Security, identity and compliance	m	m	m	R20
Identity & access management	m	m	m	R21
Security management	m	m	m	R22
Firewall management	m	m	m	R23
SQL Server	m	m	m	R24
ISO 27001	m	m	m	R25
Media services	m	s	m	R26
Windows 10	s	m	m	R27
Sql server	s	m	m	R28
windows server	s	m	m	R29
Remote Desktop Services	s	m	m	R30
webhosting	m	s	m	R31
Devops	c	m	m	R32
Business applications	c	m	m	R33
Web applications	c	m	m	R34
Digital assistant	c	m	m	R35
Mobile	m	c	m	R36
document/video/text reader	c	s	m	R37
Mobile applications	c	c	m	R38
Low-code applications	c	c	m	R39

Requirement	Case study 1	Case study 2	Case study 3	ID
Serverless	c	m	c	R40
Internet of things (IoT)	c	c	s	R41
IoT analytics	c	c	s	R42
IoT security	c	c	s	R43
IoT device management	c	c	s	R44
IoT applications	c	c	s	R45
Machine learning and AI	c	s	c	R46
open AI	c	s	c	R47
Blockchain	c	s	c	R48
Running and deploying models	c	s	c	R49
Network & content delivery	m	m		R50
Chat bots	m	m		R51
sharepoint		m	m	R52
North America	m	m		R53
kubernetes	m	m		R54
Windows	m		m	R55
Linux		m	m	R56
Red Hat Enterprise Linux (RHEL)	m	m		R57
C++	m	m		R58
JavaScript	m	m		R59
Java	m	m		R60
PowerShell	m	m		R61
Python	m	m		R62
oracle	m	m		R63
SOC 2	m	m		R64
PowerShell	m	m		R65
Python	m	m		R66
oracle	m	m		R67
SOC 2	m	m		R68
Windows 11	s	m		R69
exchange	s	m		R70
system center	s	m		R71
oracle database	s	m		R72
RHEL	s	s		R73
microsoft dynamics		m		R74
MSDN		m		R75
project server		m		R76
IBM		m		R77
United States		m		R78

Requirement	Case study 1	Case study 2	Case study 3	ID
India	m			R79
Singapore	m			R80
Europe		m		R81
Netherlands			m	R82
Germany	m			R83
France	m			R84
Ireland		m		R85
Docker Swarm	m			R86
Ubuntu			m	R87
MacOS	m			R88
Ruby		m		R89
C#	m			R90
node.js		m		R91
visual studio/WCF		m		R92
curl		m		R93
Go		m		R94
perl		m		R95
.NET		m		R96
mysql		m		R97
IBM DB2		m		R98
Redis		m		R99
Postgres		m		R100
mongodb		m		R101
GDPR		m		R102
CSA		m		R103
CIS benchmark		m		R104
SOC 1		m		R105
SOC 3		m		R106
PCI DSS		m		R107
PCI 3DS		m		R108
Banco de espana		m		R109
De Nederlandsche Bank		m		R110
AFM (netherlands)		m		R111
FCA (UK)		m		R112
PRA (UK)		m		R113
biztalk		s		R114
skype	s			R115
team foundation server		s		R116
Ubuntu			s	R117
VMware esx		s		R118

Figure 7.1: Case study requirements

vital for the company's business operations. The decision to rely heavily on Outskill for its multi-cloud architecture is motivated by several factors, primarily rooted in the company's apprehensions about running its software on competitors' platforms.

The foremost reason driving this decision is the sensitivity of the data they handle, including critical information such as product designs and engineering data. The software producer can exercise greater control over data security and compliance by utilizing their in-house infrastructure provider, ensuring strict adherence to industry regulations.

Additionally, as Outskill is an in-house solution, it may have been purpose-built and optimized to cater specifically to the performance requirements of its software and services. The company is concerned that other cloud platforms may not offer the same level of customization and performance, potentially leading to operational challenges.

Moreover, the software producer' software and services are deeply integrated with their proprietary infrastructure. Transitioning to other cloud platforms could entail significant efforts and resources for reintegration, posing risks of operational disruptions and inefficiencies.

Furthermore, over time, the company has developed a high level of trust and confidence in the reliability of Outskill as its infrastructure provider. This trust factor may contribute to their hesitation in exploring other cloud platforms, as they prioritize the reliability and consistency of their existing infrastructure.

While the software producer acknowledges potential improvements that could be achieved by adopting platforms like AWS for cost optimization, the cost is not a primary concern for the company.

In conjunction with their in-house solutions through Outskill, the software producer incorporates data management tools from Microsoft Azure into their multi-cloud architecture. This strategic integration of Azure's robust and scalable data services empowers the company to efficiently handle and process vast amounts of data, ensuring seamless data storage, retrieval, and analysis while adhering to stringent industry regulations and enhancing data security measures.

To reinforce access management and identity control, the software producer utilizes access management solutions from Okta. Okta's advanced authentication and authorization capabilities bolster the overall security posture of their multi-cloud environment, ensuring that only authorized personnel can access sensitive data and resources, thereby mitigating the risk of unauthorized access and data breaches.

Moreover, the software producer incorporates various other Software as a Service offerings into their multi-cloud ecosystem, such as Zoom, a popular video conferencing solution, which is tailored to address specific operational requirements for virtual meetings, collaboration, and communication across the organization.

By thoughtfully orchestrating this intricate multi-cloud architecture, the software producer achieves a balanced and comprehensive approach to cloud computing. Their in-house solutions, powered by Outskill, provide a secure and tailored foundation, while the integration of Azure, Okta, and other SaaS offerings delivers enhanced functionalities and features, addressing various business needs.

This multi-cloud approach empowers the software producer to optimize performance, scalability, and cost-effectiveness while fostering innovation and agility. By remaining at the vanguard of cloud technology and leveraging the strengths of various service providers, the software producer remains well-positioned to excel in the competitive landscape of software solutions and continue delivering cutting-edge products and services to their global customer base.

7.1.2 Requirements

Given the decision model the following requirements were indicated:

1. The "must-have" requirements, considered essential for the multi-cloud adoption, mainly focused on data management (R01 to R06) and infrastructure services (R07 to R12, R36, R50). These aspects were deemed crucial for the company's business operations, warranting their inclusion as mandatory elements in the decision model. Developer tools (R11) were also recognized as essential, with the Command Line Interface (R12) being specified as a "must-have" requirement, indicating its indispensability for the development process. Conversely, low-code applications (R39) were not

in use, leading to their classification as "not important" and considered as "could-have" elements. Similarly, the DevOps methodology (R32) was deemed non-essential but still considered a potential "could-have" feature. Regarding mobile platforms, having mobile capabilities (R36) was classified as a "must-have" due to its importance in the organization's digital strategy. However, while web and mobile applications were deemed important, they were categorized as "could-have" requirements, since they have in-house developers covering these requirements with their own methods. As IoT services (R41 to R45) were not utilized in the software producer' core business, they were considered "could-have" elements. Similarly, Machine Learning and AI (R46 to R49) were not needed in the current business model, leading to their categorization as "could-have" features. The exception was chatbots (R51), classified as a "must-have" due to their relevance in meeting customer needs. Management and governance services (R13 to R16) were regarded as necessary, with all services in this category marked as "must-have" due to their significance in ensuring effective cloud management and compliance. Media services (R26) were also classified as a "must-have," attributed to their role in supporting marketing initiatives and enhancing the organization's visibility. Migration and transfer services (R17 to R19) were identified as important, deemed necessary for facilitating smooth transitions to the cloud environment. Security, identity, and compliance services (R20 to R23) were considered vital, with all services in this category marked as "must-have" to ensure robust data security and regulatory compliance. Finally, serverless computing (R40) was not deemed important since it was not utilized in the organization's operations, leading to its classification as a "could-have" feature, indicating it was not a priority.

2. The "bring your own license" category was evaluated as a non-essential but desirable aspect for their multi-cloud adoption. This categorization led to its classification as a "should have" requirement, indicating that while it is not a critical necessity, it still holds value and could be beneficial for the organization. The reason behind considering "bring your own license" as a "should have" is primarily due to the company's existing licensing portfolio, which includes various software products such as Windows 10 and 11 (R27 and R69), SQL and Windows Server (R28 and R29), Skype (R115), Exchange (R70), System Center (R71), Remote Desktop Services (R30), Red Hat Enterprise Linux (R73), and Oracle Database (R72).

3. The identification of mandatory data center locations was a crucial aspect of their multi-cloud adoption strategy. These data centers were primarily concentrated in North America (R53), a central hub for the company's global operations. In addition to the North American data centers, the software producer also recognized the significance of having data center locations in other regions to effectively serve their extensive supply network, comprising 192 countries. For the Asian region, India (R79) and Singapore (R80) were identified as essential locations. For Europe, Germany (R83) and France (R84) were highlighted as important data center locations.

4. The adoption of Kubernetes (R54) and Docker Swarm (R86) for containerization purposes is a significant strategic decision. Containerization is a technology that allows applications and their dependencies to be packaged in a standardized and isolated environment, ensuring consistency and portability across various computing environments. The decision to use both Kubernetes and Docker Swarm suggests that the software producer may have a diverse set of applications and workloads with varying needs.

5. The selection of operating systems (OS) plays a crucial role in their IT infrastructure

and application ecosystem. The organization currently employs three primary operating systems: Windows (R55), RHEL (R56), and MacOS (R88).

6. The selection of programming languages is a critical aspect of their software development and service deployment strategy. The organization has identified several programming languages that are deemed imperative to support, and these languages are chosen based on their specific use cases and the services they are associated with. The programming languages listed include C# (R90), C++ (R58), JavaScript (R59), Java (R60), PowerShell (R65), and Python (R66).

7. The selection of database systems is a crucial aspect of their data management strategy. The organization has identified SQL Server (R24) and Oracle (R63) as their designated database systems, indicating their importance and priority in supporting the company's various applications and services.

8. Compliance considerations are critical in ensuring the security and trustworthiness of their services and data handling practices. Two specific compliance standards have been identified as imperative for the organization's operations: ISO 27001 (R25), which is an international standard for information security management systems (ISMS). Achieving ISO 27001 compliance is crucial for the software producer as it demonstrates their commitment to robust information security practices and risk management. SOC 2 (R68), which stands for Service Organization Control 2, is an auditing standard developed by the American Institute of CPAs (AICPA). It is particularly emphasized by the software producer, as it carries greater relevance within the American context.

7.1.3 Results

In the evaluation of CSPs using the multi-cloud decision framework, the software producer examined their specific requirements and how well each CSP fulfilled them. The analysis indicated that AWS successfully met all of the software producer' requirements, suggesting that a multi-cloud environment might not be an absolute necessity for them.

Upon further examination, it was observed that Azure, the second option, only had one requirement that was not fully met, namely the native support for Oracle database. This could imply that Azure could be a viable single-cloud option for the software producer, with the majority of their requirements being fulfilled.

Google, the third option, had some drawbacks in terms of infeasible programming languages and limited native operating system support. These limitations may make Google less ideal as a single-cloud provider for the software producer, but it doesn't necessarily rule out its potential benefits in specific use cases.

Despite the results showing that a multi-cloud setup might not be essential from a requirement fulfillment standpoint, the software producer wants to leverage the best-in-market services available, and this is where the concept of utilizing multiple cloud providers with their USPs comes into play. The decision to adopt multi-cloud is driven by the ambition to access top-notch services from various providers, combining their strengths to achieve optimal performance, redundancy, and reliability.

Upon evaluating the results and comprehending the underlying reasoning provided by the software producer, the decision framework demonstrated its alignment with the current scenario, offering a precise and validated recommendation. This shows the validity of the framework.

In the subsequent analysis, the software producer can delve deeper into the specific advantages offered by each cloud provider's USPs and how they complement their business objectives. This could include considerations of specialized services, pricing models, data residency options, compliance standards, and other factors that contribute to the software producer' vision of an ideal cloud infrastructure. By leveraging multiple cloud providers, the software producer aims to create a robust and flexible cloud strategy tailored to their unique demands and objectives, maximizing the benefits of a multi-cloud approach while mitigating potential drawbacks.

7.1.4 Analysis

The software producer, a prominent software company, recognizes the significance of their infrastructure within their sector. Their infrastructure management is deemed so critical that they have their own provider, "outskill," to handle it. Despite the growing popularity of cloud adoption, barriers such as security and privacy concerns persist in the industry. The software producer' business-critical software and fear of potential data leaks in competitors' environments exemplify these prevailing barriers, underlining the importance of maintaining control over their infrastructure. While cloud services are utilized through Software as a Service (SaaS) providers to enhance their environment, the software producer still seeks to leverage multiple cloud providers' unique selling points (USPs) through a multi-cloud approach.

The software producer' cloud services analysis revealed that they had not internally utilized Machine Learning and AI services or IoT, which were not considered core to their business. Serverless was also not extensively used, indicating limited interest in that service. The Bring Your Own License (BYOL) category was desirable but not a dealbreaker, and the cost-benefit of licensing was only a nice-to-have consideration. With such a diverse range of licensed software already in use, the organization may have invested significantly in these licenses and acquired valuable rights and privileges. However, despite the potential benefits, "bring your license" was not considered a "must-have" requirement because it does not directly impact the core functionalities of their multi-cloud ecosystem.

While the software producer serves 192 countries, they expressed that a limited number of data centers in popular regions could sufficiently cater to neighboring countries' needs. North America is a strategic choice for data center locations due to its robust technology infrastructure, reliable power supply, and advanced networking capabilities. India is known for its large and growing technology market, while Singapore serves as a key connectivity and business hub in Southeast Asia. Having data centers in these regions ensures low-latency access and reliable services for customers and partners in the Asian market. Germany is a leading economic powerhouse in Europe and is known for its strict data protection regulations, making it a reliable choice for data storage and management. France, being the home country of the software producer, holds strategic significance and may serve as a critical location for their European customer base. By strategically selecting data centers distributed across these regions, the organization can enhance the overall user experience, reduce latency, and meet data residency requirements imposed by various countries' regulations.

Interestingly, API support was deemed too technical for the case participant, implying that decision-makers might struggle with the complexity of this category. On the other hand, container orchestration was considered important for consistent application deployment and management across diverse cloud environments. Kubernetes might be employed for large-scale, mission-critical applications with high availability and scalability demands. At the same time, Docker Swarm might be used for smaller projects or applications that require a more straightforward and streamlined container orchestration solution. By utilizing both Kubernetes and Docker Swarm, the software producer can leverage the strengths of each platform to optimize their containerized applications' performance, management, and scalability. Docker Swarm and Kubernetes were known and preferred, while other options were considered less popular and unnecessary.

Furthermore, ensuring support for preferred operating systems and programming languages was essential for the development team. Their operating systems were most likely preferred due to the following reasons. At first, Windows was one of the most widely used operating systems in the world, known for its user-friendly interface and extensive compatibility with a wide range of software applications. The software producer' use of Windows indicates that many of their applications and software tools are designed and optimized to run on this platform. It is particularly prevalent in enterprise environments, where it provides a stable and familiar computing environment for employees and facilitates seamless integration with Microsoft's suite of productivity tools. Second, RHEL is a popular Linux distribution that offers a robust and secure operating system environment. The choice of RHEL suggests that the software producer relies on Linux-based systems to support specific applications or services. Linux is renowned for its stability, scalability, and performance, making it a preferred choice for server environments and applications requiring high computational power. Moreover, the open-source nature of Linux provides flexibility and customization options, allowing organizations to tailor the OS to their specific needs. At last, MacOS is an operating system designed exclusively for Apple's Mac computers. Its inclusion in the software producer' operating system portfolio indicates that the organization supports Apple devices, such as MacBooks or iMacs, as part of their computing infrastructure. The use of these three operating systems suggests that the software producer has a diverse IT environment with a mix of Windows-based systems for general computing needs, RHEL for more specialized and performance-demanding tasks, and MacOS to support Apple device users within the organization.

The programming languages implicated the following usages. C# is a programming language developed by Microsoft and is commonly used for developing applications on the .NET framework. The software producer may prioritize C# for certain services or applications that require integration with Microsoft technologies or run on the .NET platform. C++ is a versatile programming language known for its performance and low-level memory manipulation capabilities. The software producer may prioritize C++ for specific projects or services that demand efficient memory management and computational power. JavaScript is a widely used programming language for front-end web development. Given the importance of web applications and web-based services, the software producer considers JavaScript as a "must-have" language to support their web-based software. Java is a platform-independent, object-oriented programming language commonly used for building enterprise-level applications. The software producer may prioritize Java for services that require portability and scalability across different environments. PowerShell is a scripting language developed by Microsoft, specifically designed for system administration and automation tasks in Windows environments. The software producer may consider PowerShell essential for managing and automating various aspects of their IT infrastructure. Python is a high-level, versatile programming language known for its simplicity and readability. The software producer may prioritize Python for projects involving data analysis, machine learning, or other AI-related initiatives.

The software producer currently utilizes SQL Server and Oracle databases, leveraging the strengths of each system. SQL Server is a relational database management system (RDBMS) developed by Microsoft. The software producer may prioritize SQL Server for applications that require seamless integration with Microsoft technologies and for managing relational data efficiently. Oracle Database is another widely used relational database management system, known for its scalability, reliability, and extensive feature set. The software producer may prioritize Oracle for their applications that demand high performance, data security, and advanced analytics capabilities. By employing SQL Server and Oracle, the software producer can benefit from the strengths of each database system. SQL Server's integration with Microsoft technologies and ease of use may be advantageous for certain projects, while Oracle's scalability and advanced capabilities may be better suited for handling complex data scenarios and high workloads.

The software producer acknowledged the importance of complying with key regulations. The ISO 27001 compliance holds significant importance for the software producer due to its global recognition and acceptance. As a multinational software company serving customers worldwide, adhering to ISO 27001 standards helps the software producer build trust with customers, partners, and stakeholders by assuring them that their sensitive data is handled with the utmost security measures. The emphasis on SOC 2 compliance suggests that the software producer places special attention on ensuring the security and privacy of customer data, especially when serving clients and conducting business activities in the United States. Compliance with SOC 2 standards demonstrates their commitment to meeting rigorous data security and privacy requirements and ensures that their services adhere to industry best practices. This highlights that decision-makers may not possess a comprehensive understanding of all business requirements, which can encompass legal, technical, and business aspectsWhile the case participant demonstrated a strong understanding of the essential compliance requirements, it became evident that they were not familiar with all the necessary compliances. This finding highlights the fact that decision makers may not possess comprehensive knowledge of every aspect of the organization.

The multi-cloud decision framework offered valuable insights to the software producer. The analysis of partnerships, combination use cases, and customer ratings proved beneficial in identifying compatible providers for multi-cloud adoption. While customer ratings were informative, they were relatively similar and were not fully utilized at the given time. Additionally, unique selling points (USPs) played a crucial role, especially in selecting SaaS products. While Service Level Agreements (SLAs) were recognized as important, they were not heavily considered during this analysis, as they are usually further elaborated upon during contract negotiations. Although costs were an intriguing factor, suitability was prioritized in the initial stages, with specific cost analysis left for further exploration.

The software producer was surprised to find that AWS fulfilled all their requirements, indicating that migrating to AWS alone might be efficient without the need for a multi-cloud environment. However, their aspiration for the best-in-market SaaS products, especially for security and data management, drives them to identify providers' USPs and establish a multi-cloud approach. This demonstrates that while multi-cloud may not always be required, it can become necessary depending on specific business requirements or cases.

The multi-cloud decision model assisted the software producer in identifying suitable cloud service providers, streamlining their selection process. While AWS appeared as a comprehensive single-cloud option, the software producer' goal to leverage the best-in-market services and unique strengths of various providers justified their multi-cloud adoption. The decision model serves as a valuable resource for organizations to evaluate and compare providers, aiding in the pursuit of an optimized and tailored cloud strategy to meet diverse business needs and challenges.

Other providers that demonstrated multiple infeasibilities were deemed unsuitable. Interestingly, Azure and GCP emerged as highly suitable options. Expert interviews further revealed that major CSPs primarily serve numerous companies, while smaller, specialized CSPs tend to focus on niche areas such as security. The decision model demonstrated that major CSPs generally cover all requirements. Additionally, certain CSPs like Salesforce may cater to specific divisions or services within an organization, requiring only a selective set of business requirements and programming languages.

7.2 Case study 2: Financial institution

The financial institution is a multinational life insurance, pensions, and asset management company headquartered in The Hague, Netherlands. It is one of the world's leading providers of life insurance and pension products, serving millions of customers across the globe. The company boasts a workforce exceeding 22,000 employees and provides services across more than 20 countries, including the Americas, Europe, and Asia, and has a significant presence in the financial services industry.

The financial institution offers a wide range of insurance and financial products, including life insurance, annuities, retirement plans, and investment solutions. The company caters to both individual customers and businesses, providing them with financial security and protection against various risks.

In addition to its insurance and pension offerings, the financial institution also provides asset management services, helping clients grow and manage their investments. The company's asset management arm focuses on delivering investment solutions across various asset classes, including equities, fixed income, and alternative investments.

As a prominent player in the insurance and financial services sector, The financial institution is committed to delivering value to its customers, shareholders, and other stakeholders. It emphasizes innovation and digital transformation to enhance customer experiences and streamline its operations.

Overall, the financial institution plays a crucial role in helping individuals and businesses plan for their financial future, providing them with insurance, retirement, and investment solutions to achieve their long-term financial goals and security.

7.2.1 Current situation

The financial institution, a leading multinational life insurance, pensions, and asset management company, has established a sophisticated and comprehensive multi-cloud ecosystem, skillfully leveraging the capabilities of three prominent cloud service providers: AWS, Microsoft Azure, and GCP. This strategic decision model was carefully designed to harness the unique strengths of each cloud provider and optimize their offerings to meet specific business needs and objectives.

In the multi-cloud architecture, AWS assumes a crucial role as the primary provider for PaaS offerings and infrastructure provisioning. The adoption of AWS's PaaS solutions allows the financial institution to streamline its application development and deployment processes, enabling faster time-to-market for new services and enhancements. Furthermore, AWS's robust infrastructure provisioning capabilities ensure scalability, reliability, and high performance for critical applications, ensuring seamless customer experiences and uninterrupted service delivery.

Microsoft Azure, another integral component of the financial institution's multi-cloud ecosystem, is strategically employed for efficient data management. Azure's comprehensive suite of data services and tools empowers the financial institution to effectively handle vast amounts of customer data, ensuring data security, compliance, and accessibility. Moreover, Azure's capabilities in remote desktop functionalities prove valuable in facilitating remote work scenarios and ensuring a productive and collaborative workforce.

The decision to incorporate GCP predominantly focuses on web tooling operations. GCP's suite of web application development tools and services empowers the financial institution to create and manage innovative web-based applications with agility and efficiency. Leveraging GCP's cutting-edge web tooling capabilities, the financial institution enhances its digital presence, delivering seamless online experiences to customers and stakeholders.

By thoughtfully integrating AWS, Azure, and GCP into their multi-cloud ecosystem, the financial institution benefits from the unique offerings and strengths of each cloud service provider. The decision model ensures that specific workloads and functionalities are allocated to the most suitable platform, optimizing cost, performance, and scalability. This strategic multi-cloud approach positions the financial institution to effectively navigate the dynamic and competitive landscape of the financial services industry while delivering value and innovation to its customers and stakeholders. As the cloud computing domain continues to evolve, the financial institution remains well-prepared to embrace future opportunities and challenges, driven by its versatile and carefully curated multi-cloud architecture.

7.2.2 Requirements

Given the decision model, the following requirements were indicated:

1. For the cloud services, Data management (R01 to R06) is considered a "must-have" for the financial institution, indicating its critical importance in ensuring effective handling, storage, and security of their data assets. As a financial services company, the financial institution deals with vast amounts of sensitive customer information and financial data. Robust data management solutions are essential for maintaining data integrity, confidentiality, and compliance with regulatory requirements. However, Blockchain technology (R48) was not considered as important for the financial institution's current business operations, resulting in its classification as a "should-have." While blockchain offers various benefits in terms of transparency and security for financial transactions, the financial institution may not have immediate use cases for it in their existing processes. Infrastructure services (R07 to R10, R50) are deemed essential for the financial institution, ensuring the smooth operation and availability of their cloud-based applications and systems. However, it is mentioned that web hosting (R36) is managed in-house and not needed in the cloud, resulting in its classification as a "should-have." This decision may be influenced by existing investments in on-premises web hosting infrastructure. Developer tools and CLI (R11-R12), are considered essential for the financial institution, facilitating the efficient development and deployment of software applications. However, low code applications (R32) are not utilized, making them less important. On the other hand, the DevOps methodology (R39) is classified as "must-have," indicating the organization's emphasis on streamlining collaboration between development and operations teams to accelerate software delivery and enhance IT agility. While having a mobile (R36,R38) platform is considered important, it is not deemed essential ("could-have") for the financial institution's current operations. However, web applications (R34) are used extensively and are classified as a "must-have," suggesting that the financial institution places greater importance on web-based user interfaces for its services. IoT technologies (R41 to R45) were not utilized for the financial institution's core business operations, resulting in its classification as a "could-have." This indicates that while IoT has potential applications, it is not immediately critical for the financial institution's existing services. Although not currently utilized in their business model, the financial institution considers machine learning and AI (R37,R46,R47,R49) as a "should-have" due to their plans to adopt these technologies in the future. Machine learning and AI can enhance various aspects of financial services, such as risk assessment, fraud detection, and customer service. Chatbots (R51) and digital assistants (R35) are deemed necessary for the financial institution, driven by customer and employee demand for such functionality. Management and governance services (R13 to R16) are considered important

("must-have") for the financial institution to ensure efficient administration, monitoring, and compliance of their cloud resources and services. Media services (R26) are not classified as a "must-have" for the financial institution since they do not heavily focus on marketing activities themselves. Migration and transfer services (R17 to R19) are deemed important ("must-have") by the financial institution as they play a vital role in ensuring a smooth transition to the cloud environment, minimizing downtime, and avoiding data loss during the migration process. Security, identity, and compliance services (R20 to R23) are of utmost importance ("must-have") for the financial institution, given the sensitive nature of their financial data and the need to comply with stringent regulatory requirements. Serverless (R40) computing is classified as a "must-have" for the financial institution since they are already using it in their business operations. Serverless architecture enables them to run applications without managing underlying server infrastructure, leading to cost savings and increased scalability.

2. Due to cost considerations and the possession of multiple licenses, the "bring your own license" approach is deemed a "must-have" for the financial institution. This approach allows the organization to utilize existing licenses for essential software products, thereby optimizing licensing costs and avoiding additional expenses. The "must-have" licenses include Windows 10 and 11 (R27 and R69), SQL and Windows Server (R28 and R29), Microsoft Dynamics (R74), SharePoint (R52), Exchange (R70), System Center (R71), Remote Desktop Services (R30), MSDN (R75), Project Server (R76), Oracle Database (R72), and IBM (R77) licenses. These licenses are critical for the financial institution's core business operations and must be brought into the cloud environment to maintain continuity and compliance. Under the "should-have" category for the BYOL approach, licenses for RHEL (R73), Team Foundation Server (R116), and BizTalk (R114) are included. Although not deemed essential, these licenses are considered desirable and advantageous to have in the cloud environment. RHEL might be needed for specific applications or functionalities, while Team Foundation Server and BizTalk offer benefits in terms of collaboration and integration capabilities. While these licenses are not crucial for day-to-day operations, their inclusion as "should-have" indicates their potential to enhance the financial institution's cloud infrastructure and operations if integrated.

3. Given the financial institution's dispersed geographical locations across different countries, the aspect of geolocation played a pivotal role in their decision-making process for adopting cloud services. A "must-have" requirement was identified, necessitating the establishment of a cloud presence in both North America (R53) and Europe (R81). These regions are considered prerequisites for the financial institution's cloud strategy, as they align with the organization's core business operations and customer base.

4. For the financial institution, container orchestration, particularly through the use of Kubernetes (R54), was identified as a critical and "must-have" component in their cloud infrastructure. The categorization of Kubernetes as a "must-have" highlights its essential role in the financial institution's cloud strategy. By adopting Kubernetes for container orchestration, the financial institution can efficiently manage and deploy their containerized applications, enabling better resource utilization and scalability.

5. The financial institution considers RHEL (R57) as a "must-have" operating system. RHEL is a widely used and well-established Linux distribution known for its stability, security, and reliability. The financial institution utilizes VMware ESXi (R118) as a hypervisor for virtualization. While VMware ESXi is an important component for

managing virtual machines and optimizing server resources, the financial institution considers it a "should-have" operating system.

6. The financial institution's uses multiple "must-have" programming languages, including Ruby (R89), C++ (R58), Node.js (R91), JavaScript (R59), Java (R60), PowerShell (R61), Visual Studio/WCF Curl (R92, R93), Python (R66), Go (R94), Perf (R95), and .NET (R96), which reflects the critical role these languages play in supporting various aspects of their business. Each programming language serves specific purposes, such as web development, system programming, automation, and more.

7. The financial institution's usage of multiple "must-have" database management systems, including MySQL (R97), SQL Server (R24), IBM DB2 (R98), Oracle (R67), Redis (R99), PostgreSQL (R100), and MongoDB (R101), reflects the critical role these systems play in managing various types of data within their organization. Each DBMS serves specific purposes, such as managing relational data, supporting real-time data processing, and handling unstructured data.

8. In terms of compliance, several global regulatory standards assumed critical importance. GDPR (R102)is a critical compliance requirement for the financial institution, given its operations in the European Union (EU) and handling of personal data of EU citizens. CSA (R103) and CIS (R104) provide best practices and guidelines for securing cloud-based infrastructure and services. ISO 27001 (R25) is an internationally recognized standard for information security management systems. Implementing ISO 27001 is crucial for the financial institution to establish a robust security framework, identify risks, and implement controls to safeguard its information assets effectively. SOC (R105,R68,R68) reports are essential for organizations like the financial institution that provide services to clients. SOC reports assess and demonstrate the effectiveness of internal controls related to financial reporting, data security, and privacy. As the financial institution likely handles payment card transactions, compliance with PCI DSS (R107) is essential. Given the financial institution's international operations, it should prioritize compliance with the financial regulations of the countries it operates in (R108 to R113). While these regulations may vary by country, they are essential for the organization to conduct its financial services in a legally compliant manner.

7.2.3 Results

Based on the specified requirements, it was determined that no single CSP fully met all the criteria. Azure exhibited the closest alignment with the requirements, closely followed by AWS and Google. Consequently, a hybrid approach combining Azure with either AWS or Google was deemed capable of satisfying all the identified requirements. However, it is noteworthy that the financial institution primarily utilized AWS as its primary infrastructure while incorporating the other suggested providers. The decision to select AWS as the central cloud provider stemmed from its established maturity and robustness at the time of procurement. Notably, five years prior to their adoption, Azure's maturity level was comparably lower than that of AWS, thereby influencing the financial institution's choice of the latter as their primary cloud platform.

Upon evaluating the results and comprehending the underlying reasoning provided by the participants, the decision framework demonstrated its alignment with the current scenario, thereby offering a precise and validated recommendation. This shows the validity of the framework.

In pursuit of establishing a multi-cloud environment, the financial institution incorporates additional cloud providers, primarily for the purpose of adopting SaaS applications aligned with their unique selling propositions USPs. The driving factor behind this approach is the financial institution's emphasis on acquiring the best-in-market applications, prioritizing quality and functionality over cost considerations. By leveraging multiple cloud providers for specific SaaS applications, the financial institution aims to access a diverse range of specialized and top-tier solutions available in the market. The multi-cloud strategy enables them to capitalize on the strengths and distinct features offered by different cloud providers, thereby enhancing their overall application landscape and delivering optimal value to their stakeholders.

7.2.4 Analysis

The financial institution, a prominent player in the financial industry, revealed their multi-cloud adoption strategy during the analyses. The company primarily utilizes AWS as its main cloud provider and supplements it with other CSPs based on their unique selling points (USPs) or internal expertise. The decision to opt for AWS was based on its maturity at the time of migration, which occurred approximately five years ago. Back then, AWS was the most mature CSP, while Azure was still in its nascent stage, primarily focusing on licensing rather than cloud services. As we delve into the financial institution's business requirements and CSP preferences, we gain insights into their considerations for multi-cloud adoption.

In the context of the financial industry, the financial institution identified certain business requirements for their cloud services. Notably, they had not yet utilized IoT services and had yet to explore the full potential of machine learning and AI. Although not deemed immediately important, the financial institution considered these services for future consideration. Chatbots and digital assistants were deemed important, since AI-driven conversational interfaces can improve customer support, automate routine tasks, and enhance user experiences. Additionally, the company's extensive use of licenses motivated them to prioritize bring-your-own-license (BYOL) services to reduce costs where possible.

Regarding data center locations, the financial institution recognized that they only required two locations: Ireland and the United States. These strategically chosen locations served as central points, effectively catering to neighboring countries in Europe and the US. The presence of cloud data centers in North America and Europe is crucial to ensure low-latency access to cloud services for customers, employees, and business partners in these regions. By strategically selecting these geolocations, the financial institution aims to enhance the overall performance, reliability, and responsiveness of its cloud-based applications and services for users within these critical markets.

API support was intriguing for the financial institution, but the case participant found it to be somewhat technical, requiring further evaluation.

Container orchestration emerged as a crucial requirement for the financial institution, ensuring consistent application deployment and management across diverse cloud environments. For this purpose, the financial institution identified Kubernetes as the preferred solution. Kubernetes provides a robust framework for automating the deployment and scaling of containers, ensuring that the financial institution's applications can seamlessly handle varying workloads and traffic demands. Furthermore, Kubernetes' compatibility with various cloud providers allows the financial institution to achieve multi-cloud or hybrid cloud deployments, enhancing flexibility and avoiding vendor lock-in. This aligns with the financial institution's strategic approach to cloud adoption, where the organization may choose to utilize services from multiple cloud providers based on specific needs and cost considerations.

The organization opted for the adoption of the RHEL and VMware ESXi operating systems. By adopting RHEL, the financial institution can benefit from a robust and secure operating system that provides excellent support for running critical business applications. The "must-have" classification indicates that RHEL is an essential and non-negotiable component of their operating system infrastructure. The "should-have" classification suggests that although VMware ESXi plays a significant role in their infrastructure, it is not considered business-critical. This means that while the financial institution recognizes the value and benefits of using VMware ESXi, it is not an indispensable requirement for their core business operations. The distinction between "must-have" and "should-have" criteria helps the financial institution prioritize their resources and investments in operating systems. By categorizing RHEL as "must-have," the financial institution ensures that the foundational and critical operating system is in place to support their primary business functions. On the other hand, classifying VMware ESXi as "should-have" allows the financial institution the flexibility to evaluate its importance in the context of specific use cases, resource allocation, and cost considerations. Surprisingly, despite their significant use of Windows licenses, the financial institution did not prioritize support for the Windows operating system, as they predominantly relied on Linux.

The financial institution's organization utilized a wide range of programming languages. Ensuring support for these was a crucial aspect in their evaluation of CSPs. Ruby is a dynamic, object-oriented language known for its simplicity and productivity. It is commonly used for web development, scripting, and automation tasks. By considering Ruby as a "must-have," the financial institution acknowledges its importance in supporting critical applications and workflows within their organization. C++ is a powerful, general-purpose programming language widely used for system-level programming and performance-critical applications. Its versatility and efficiency make it suitable for various applications, and its "must-have" classification indicates that it plays a vital role in the financial institution's software development. The financial institution also considers Node.js and JavaScript as part of its technology stack. JavaScript is a popular language used for web development, while Node.js allows JavaScript to be executed on the server-side, enabling scalable and efficient web applications. The financial institution's classification of these languages as "must-have" highlights their significance in building web-based applications and services. Java is widely used for building enterprise-level applications, and its portability and scalability make it suitable for large-scale projects. By designating Java as a "must-have," the financial institution emphasizes its importance in supporting various enterprise applications and services. PowerShell is a task automation and configuration management framework developed by Microsoft. PowerShell is commonly used for automating administrative tasks and managing systems and applications in a Windows environment. The financial institution considers Visual Studio/WCF Curl as a "must-have" programming language and framework. Visual Studio is an integrated development environment (IDE) used for building a wide range of applications, and WCF is a framework for building service-oriented applications. Curl is a command-line tool used for transferring data with URLs. Together, these tools and frameworks play a vital role in the financial institution's development and communication infrastructure. Python is a versatile and widely used language known for its readability and ease of use. It is employed for web development, data analysis, scripting, and automation. By designating Python as a "must-have," the financial institution recognizes its value in various domains within their organization. Go is a statically typed language developed by Google, known for its concurrency support and performance. It is commonly used for building scalable and efficient web services and applications. The financial institution's classification of Go as a "must-have" indicates its significance in powering critical components of their software infrastructure. Perf, short for performance, is typically associated with performance measurement and analysis tools, further context would be needed to determine its specific usage in the financial institution's environment. In any case, its "must-have" classification suggests that it plays a vital role in monitoring and optimizing the performance of their applications. .NET, a framework developed by Microsoft, provides a rich set of libraries and tools for building Windows-based applications and web services. By considering .NET as a "must-have," the financial institution acknowledges its importance in supporting their Windows-based software and services.

The financial institution employs a diverse range of database systems in its operations. MySQL is a popular open-source relational database management system used extensively by the financial institution. Its "must-have" classification indicates that it plays a critical role in storing and managing relational data within their applications and systems. SQL Server, a product of Microsoft, is widely used for enterprise-level applications and provides robust support for managing and querying relational data. Its "must-have" status emphasizes its importance in the financial institution's data management infrastructure. IBM DB2 is a robust and scalable database system commonly used in enterprise environments. Its inclusion as a "must-have" indicates that it is essential for supporting specific business-critical applications and workloads within the financial institution. Oracle Database is a powerful and feature-rich relational database management system utilized in large-scale enterprises. Its "must-have" status reflects its crucial role in managing complex data requirements and supporting mission-critical applications at the financial institution. Redis is an in-memory data structure store often used as a database, cache, and message broker. The financial institution's classification of Redis as a "must-have" suggests its significance in supporting real-time data processing, caching, and other high-performance use cases. PostgreSQL, commonly referred to as Postgres, is an open-source, powerful relational database system known for its extensibility and advanced features. Its "must-have" status signifies its importance in the financial institution's data management and analytics initiatives. MongoDB is a NoSQL database, suitable for storing and handling unstructured or semi-structured data. Its "must-have" status suggests its role in supporting modern applications that require flexible and scalable data storage solutions.

Moreover, compliance standards were of paramount importance, especially considering the financial institution's goal to serve multiple European countries, each with distinct compliance requirements. Compliance with GDPR is a "must-have" for the financial institution to ensure the lawful and secure processing of personal data and maintain trust with its customers.However, the case participant was uncertain about whether the compliance standards offered by CSPs like Azure were sufficient for their specific needs. The financial institution, being a financial institution, must prioritize CSA and CIS standards as "must-have" to enhance the security posture of its cloud deployments and protect sensitive financial data from potential threats and breaches. ISO27001 compliance requirement is a "must-have" to ensure the confidentiality, integrity, and availability of critical business information. As a financial institution, the financial institution must comply with SOC 1, SOC 2, and SOC 3 requirements to assure clients of the integrity of its financial processes and the security of their data. PCI compliance is a "must-have" to protect cardholder data during payment processing and maintain the trust of customers who use payment cards for transactions. The "must-have" compliance requirements ensure the organization's adherence to key data protection, security, and financial standards, which are fundamental to its reputation, operations, and customer trust. The "should-have" compliance consideration emphasizes the importance of complying with specific financial regulations in different countries to ensure continued international operations in a compliant manner.

After prioritizing their requirements, the financial institution explored partnerships and combination use cases to assess compatibility between CSPs. This analysis proved valuable and insightful. Customer ratings were also considered, although they were largely similar, warranting further investigation. The case participant commended the decision model for providing a shortlist of suitable CSPs, while suggesting that customer ratings could be thoroughly researched after creating this shortlist.

The financial institution's use of USPs to identify market leaders and potential CSPs for collaboration in their multi-cloud environment demonstrated a strategic approach. While SLAs were deemed important, the participant acknowledged that they are better addressed during contract negotiations with CSPs. Cost considerations were interesting but ultimately case-specific, and the financial institution, being a large company, prioritized compatibility over cost-effectiveness when selecting CSPs.

A notable revelation was that, in a multi-cloud environment, the financial institution emphasized minimal communication between clouds unless absolutely necessary. This approach aimed to reduce complexity and latency, leading them to favor using multiple providers and leveraging their functionalities on their respective infrastructures.

The decision model presented aligns with the financial institution's approach, though it emphasizes Azure over AWS. The case participant confirmed that they were indeed shifting towards Azure, in line with the decision model's results. This finding suggests that the decision model accurately reflects the financial institution's evolving cloud adoption strategy.

The analysis of the financial institution's multi-cloud adoption approach sheds light on their considerations, priorities, and preferences. Their current reliance on AWS as the primary provider, supplemented by other CSPs with unique offerings, reflects their strategic approach to multi-cloud architecture. Key insights, such as their interest in Kubernetes, BYOL services, and compliance standards, serve as essential considerations for businesses contemplating multi-cloud adoption. As the industry evolves, the financial institution's flexibility in embracing new services like IoT, AI, and different CSPs exemplifies their readiness for future advancements in the cloud landscape. Ultimately, the financial institution's experience underscores the importance of aligning business requirements with the right combination of CSPs to achieve a successful multi-cloud strategy.

7.3 Case study 3: Educational institution

The educational institution is a regional educational institution in the Netherlands. They provide vocational education and training to students in various fields, preparing them for the job market or further higher education.

The institution offers a wide range of vocational programs, including courses in business, healthcare, technology, hospitality, creative industries, and more. These programs are designed to equip students with practical skills and knowledge relevant to their chosen career paths.

The educational institution collaborates closely with local businesses, industries, and organizations to ensure that their educational programs align with the needs of the job market. This approach helps students develop the skills and competencies that are in demand by employers, increasing their employability upon graduation.

The institution has multiple campuses across the region, each specializing in different fields of study. These campuses provide modern facilities and resources to support students' learning experiences.

Overall, the educational institution plays a crucial role in the Dutch educational landscape by offering vocational education and training that contributes to the personal and professional development of students and meets the workforce demands of the region. The educational institution operates within the confines of the Netherlands, operating with a staff of 2,000 members and catering to an approximate student population of 20,000 individuals.

7.3.1 Current situation

The educational institution, the organization under study, has adopted a strategic approach by selecting Azure as its primary infrastructure provider. By doing so, they have established a comprehensive decision model to facilitate the development and deployment of a diverse range of SaaS applications within the Azure environment. Although they are currently in the process of transitioning to the cloud, they still maintain a server park alongside their cloud infrastructure. Additionally, the educational institution leverages SURF, an organization that assists in making IT decisions and provides access to multiple licensing options, enhancing their IT capabilities.

It is noteworthy that the educational institution has integrated SaaS offerings from prominent providers such as Salesforce and AFAS into their operations. These collaborations enable the organization to access specialized SaaS applications that cater to specific business needs effectively. Leveraging services from reputable SaaS providers allows the educational institution to benefit from the expertise and technological advancements offered by these industry-leading companies.

In the realm of educational-specific SaaS applications, the educational institution has adopted a strategic approach by partnering with local vendors. This decision demonstrates their willingness to work closely with providers who possess a deep understanding of the local educational landscape and can tailor their solutions to suit the unique requirements of the organization.

As the educational institution continues its journey towards cloud adoption, their reliance on Azure as the primary infrastructure provider showcases a preference for a well-established and widely-used cloud platform. This choice aligns with the organization's decision model and is likely driven by the robust features, scalability, and global presence offered by Azure.

The educational institution's hybrid approach, combining both cloud and on-premises infrastructure, suggests a prudent approach to migration, enabling them to carefully manage the transition process. The organization's collaboration with SURF further signifies a strategic effort to leverage external expertise and resources to optimize their IT decision-making and licensing processes.

In conclusion, the educational institution's adoption of Azure as its primary infrastructure provider, along with its utilization of SaaS offerings from prominent providers and partnerships with local vendors, exemplifies a thoughtful and well-considered approach to cloud adoption. By employing a decision model tailored to their unique needs, the organization can navigate the cloud landscape effectively and continue to enhance their IT capabilities in alignment with their business objectives.

7.3.2 Requirements

Given the decision model, the following requirements were indicated:

1. During the evaluation of cloud services, the importance of various features was determined based on their relevance to the organization. Data management (R01 to R06) was identified as a "must-have" feature because it is essential for the organization's day-to-day operations. Effective data management ensures the proper storage, organization, and retrieval of information, which is crucial for the smooth functioning of educational and administrative processes. Blockchain technology (R48) was classified as a "could-have" feature since the organization does not currently utilize it. While blockchain has various applications, its immediate relevance to the organization's core operations might be limited, but it remains an option for future consideration. Infrastructure (R07 to R10, R50) and developer tools (R11,R12,R32,R39) were also catego-

rized as "must-have" features. These tools are critical in supporting the organization's activities, including application development, deployment, and maintenance. Availability of business applications (R33), mobile (R34) and web applications (R38) were deemed "must-have" requirements. Business applications streamline various processes within the organization, while mobile functions allow for accessibility and productivity on the go, facilitating efficient communication and collaboration. The IoT (R41 to R45) was categorized as a "should-have" feature because it was not currently implemented but holds potential for future integration. As the organization explores new technologies, IoT may offer opportunities for innovative educational applications and improved campus management. Machine learning and AI (R46 to R49) were identified as "could-have" features because they are not extensively used within the organization's current operations. However, specific functionalities such as document readers (R37) and digital assistants (R35) were considered "must-haves" due to their perceived importance. Document readers can enhance document accessibility and improve learning experiences, while digital assistants can simplify tasks and provide valuable support. Management and governance features (R13 to R16 were identified as "must-have" since they are crucial for effective cloud operations. These features help in monitoring, managing, and governing cloud resources, ensuring compliance, cost optimization, and overall cloud service efficiency. Media services (R26) were categorized as "must-have" due to their significance in effective cloud operations. These services facilitate the storage, processing, and delivery of media content, which may be essential for educational materials and communication within the organization. Transfer and migration features (R17 to R19) were also considered "must-have" as they are crucial for effective cloud operations. These features aid in seamless data transfer and migration from on-premises systems to the cloud, ensuring a smooth transition to the cloud environment. Security, identity, and compliance features (R20 to R23) were classified as "must-have" since they are vital for ensuring data security, access control, and adherence to regulatory requirements. Given the sensitive nature of educational and administrative data, robust security measures are essential. Serverless (R40) architecture was considered a "could-have" feature since it is not currently implemented. Nevertheless, the potential benefits of serverless computing, such as cost optimization and scalability, could make it a valuable addition to the organization's cloud environment in the future.

2. The "must-have" criterion for the educational institution was to adopt a BYOL approach due to cost considerations. This approach allows the organization to leverage existing licenses, which can lead to significant cost savings. By bringing their own licenses, the organization can use software and services without incurring additional licensing costs. The "must-have" licenses include Windows 10 (R27), SQL and Windows Server (R28 and R29), SharePoint (R52), and Remote Desktop Services (R30). The Ubuntu license (R117) was considered a "should-have" feature, meaning it was desirable but not essential.

3. As a Dutch company, it was a "must-have" for the organization to be stationed within the Netherlands (R82). This is crucial for the organization as a Dutch company because it ensures compliance with local data protection and privacy regulations, such as the General Data Protection Regulation (GDPR) specific to the European Union (EU) and the Netherlands' national data privacy laws.

4. The identified essential operating systems for their environment included Windows 10 (R55) and Ubuntu (R87). By considering Windows 10 and Ubuntu as "must-have" operating systems, the educational institution ensures that their cloud infrastructure is

built on reliable and widely supported platforms. Windows 10 caters to the needs of users who are accustomed to the Windows ecosystem, while Ubuntu complements the environment with its flexibility and efficiency in server-oriented tasks.

5. The organization employed SQL Server (R24) as their preferred database system. SQL Server was identified as a "must-have" database system for the organization. This decision aligns with their data management needs, indicating that SQL Server is crucial for efficiently storing, managing, and retrieving data related to various educational and administrative processes.

6. While the organization expressed uncertainty regarding specific compliance requirements, it was determined that ISO 27001 compliance (R25) was a "must-have" for their cloud adoption strategy. By achieving compliance with this standard, the organization demonstrates its commitment to implementing a robust and systematic approach to managing and protecting sensitive information.

7.3.3 Results

Considering the educational institution their specific requirements, Azure and GCP emerged as suitable cloud providers. A multi-cloud environment was not explicitly required due to the well-aligned capabilities and offerings of Azure and GCP with the educational institution's needs. Both providers were deemed to possess the necessary features, services, and infrastructure to support the organization's cloud computing objectives effectively. While a single-cloud approach could adequately fulfill their requirements, the potential benefits of a multi-cloud setup were not deemed essential in this context.

The educational institution desired a multi-cloud environment, driven by recognizing the significance of USPs, external applications, and the need to leverage the best available tooling. This decision reflects a strategic approach aimed at maximizing the benefits and capabilities offered by multiple cloud providers. By adopting a multi-cloud approach, the organization aims to access a diverse range of cloud services, tools, and features from different providers, optimizing its overall cloud infrastructure and enhancing its competitive advantage.

The decision to select Azure over GCP as their existing licensing agreements influenced their preferred cloud platform. By joining a network that grants them access to discounts and strategic guidance on their IT strategy, they aimed to optimize their operational efficiency. However, it is noteworthy to mention that they do not possess a fail-safe mechanism to mitigate the potential risks associated with vendor lock-in.

Upon evaluating the results and comprehending the underlying reasoning provided by the educational institution, the decision framework demonstrated its alignment with the current scenario, thereby offering a precise and validated recommendation. This shows the validity of the framework.

7.3.4 Analysis

The educational institution is actively pursuing a cloud-first strategy, aiming to migrate all of its legacy systems to the cloud. The organization is currently transitioning towards Azure, a process that requires careful planning and execution. Expert interviews have revealed that multi-cloud adoption, for most organizations, involves selecting one major cloud provider, such as Azure or AWS, and then extending its capabilities with SaaS applications from other providers. The educational institution aligns with this claim, as it follows a similar architecture by primarily relying on Azure while integrating SaaS offerings from various vendors. As part of a group of organizations, the educational institution's overarching IT company, SURF, plays a significant role in making IT decisions, providing benefits like discounted Microsoft licensing, which the educational institution takes advantage of. Additionally, the organization collaborates with local SaaS providers to access educational-specific software and major vendors like Salesforce for their market significance, highlighting the consideration of USPs in their decision-making.

In terms of business requirements, the educational institution exhibits a diverse array of needs. However, at the current stage, machine learning, AI, and IoT are not being utilized. Nonetheless, they acknowledge the potential future adoption of these technologies as they seek to keep up with technological advancements and integrate them into their educational offerings to benefit students. Being an educational institution, the educational institution recognizes the importance of showcasing technological advancements to its students, making future implementation of these technologies a possibility. Additionally, as AI and machine learning continue to advance, they may provide valuable insights and automation capabilities in the future.

Cost reduction is a significant factor for the educational institution, and due to the substantial amount of licensing they possess, it becomes crucial to bring down these expenses. Consequently, keeping costs low is deemed important in their multi-cloud decision-making process. Among the BYOL features, the educational institution prioritized bringing Microsoft licenses. This decision might be driven by the organization's extensive use of Microsoft products in their educational and administrative processes. Windows 10 is a widely used operating system that provides compatibility with various applications and devices. Its inclusion as a "must-have" aligns with the organization's need for a stable and familiar operating system for their educational and administrative tasks. In addition to Windows 10, SQL and Windows Server licenses were also included. SQL Server is crucial for managing databases, storing and retrieving data efficiently, which is essential for various applications and services used by the organization. Windows Server provides the infrastructure and services necessary for managing and supporting networked resources. SharePoint was prioritized due to its powerful collaboration platform that enables document management, content sharing, and team collaboration. Its inclusion as a "must-have" aligns with the organization's need to facilitate seamless communication and information sharing among staff and students.The inclusion of Remote Desktop Services (RDS) license indicates the importance of providing remote access to applications and desktops for users. RDS allows users to access their desktop environments and applications from remote locations, enhancing mobility and productivity. The Ubuntu license was considered a "should-have" feature, meaning it was desirable but not essential. Ubuntu is a popular Linux-based operating system known for its security and stability. While not as critical as the Windows licenses for the organization's current operations, having the option to bring Ubuntu licenses could be beneficial for specific use cases or future expansion into Linux-based applications.

Additionally, the location of data centers is a critical consideration, with the requirement that they be located in the Netherlands to address latency concerns and ensure compliance with regulations. Storing data within the country's borders ensures that the educational institution adheres to data sovereignty requirements and maintains control over sensitive information related to their students, staff, and operations. By choosing a data center location within the Netherlands, the educational institution can effectively comply with specific legal and regulatory frameworks applicable to educational institutions in the country. Also, Having the data center in close proximity to their operations is also critical. The geographic proximity minimizes network latency, ensuring faster access to applications and services hosted in the data center. This is particularly important for e-learning platforms, administrative systems, and other digital tools that require real-time access and responsiveness.

While API support is an essential feature of cloud services, the educational institution's case participant considered it too technical and opted not to explore this aspect further in the analysis.

Operating system support, specifically for Windows and Ubuntu, is vital to support the current workflow within the educational institution. Windows 10 was identified likely due to its widespread adoption and compatibility with a wide range of software applications commonly used in educational institutions. Windows 10 provides a familiar user interface, regular updates, and robust security features, making it a reliable choice for supporting various teaching and administrative tasks. Ubuntu, a Linux-based operating system, are known for their stability, security, and open-source nature, making them popular choices for server infrastructure and various educational applications. Utilizing Ubuntu may enable the educational institution to host web services, learning management systems, and other cloud-based applications more efficiently and cost-effectively.However, determining the full extent of programming languages utilized in the organization proved challenging during the case study and was consequently skipped in the evaluation.

For database systems, the educational institution relies on SQL Server, prioritizing its use for applications requiring seamless integration with Microsoft technologies and efficient management of relational data. The educational institution deals with a significant amount of data, ranging from student records to course materials and administrative information. By choosing SQL Server as their preferred database system, the organization ensures that they have a reliable and scalable platform to handle their data-intensive tasks effectively.

Compliance with industry standards and regulations is of utmost importance for the educational institution, although the case participant was unsure of all the specific requirements within the education domain. The decision to prioritize ISO 27001 compliance reflects the organization's recognition of the criticality of information security in today's digital landscape. As an educational institution, the educational institution handles a considerable amount of confidential data, including student records, academic information, and administrative documents. Ensuring the confidentiality, integrity, and availability of this data is of utmost importance to protect students' privacy and maintain the organization's reputation.

The partnerships and combination use cases were regarded as interesting aspects to consider when evaluating the suitability of CSP combinations. However, customer ratings were found to be too similar to make immediate decisions based on them. Instead, they were seen as a valuable input for future considerations. USPs played a crucial role in identifying CSPs that align with specific business requirements, providing a useful framework for decision-making. The case participant noted that evaluating SLAs and costs might be more effectively done in collaboration with the CSP itself since these aspects are often case-specific and depend on the use case.

Overall, the decision model proved to be highly useful for the educational institution's cloud migration efforts. It facilitated the creation of a shortlist of suitable CSPs and helped align their multi-cloud architecture with their business requirements effectively. The framework also enabled the organization to evaluate the compatibility of their existing multi-cloud solution. As the educational institution continues to pursue its cloud-first strategy, the decision model will serve as a valuable tool for guiding their cloud adoption journey and optimizing their cloud infrastructure to meet the evolving needs of their educational institution.

		Case study 1	Case study 2	Case study 3
Context	Countries active	192	20	1
	Domain	Software producer	Finance	Education
	Employee count	20000+	22000+	2000+
Requirements	Must have	64,00%	81,00%	80,00%
	Should have	13,00%	11,00%	11,00%
	Could have	23,00%	8,00%	9,00%
	Wont have	0,00%	0,00%	0,00%
	Feature requirements	75	102	56
Evaluation	Providers used	Main provider: Outskill Combined: AWS, Azure, smaller SaaS	Main provider: AWS Combined: Azure, GCP	Main provider: Azure Combined: Saas providers
	Providers suggested	Main provider: AWS Combined: Azure, IBM, GCP	Main provider: Azure Combined: AWS, GCP	Main provider: Azure or GCP Combined: SaaS providers

Figure 7.2: The overall requirement priorization, as well as the existing and proposed solutions for the corresponding multi-cloud environments

Chapter 8

Discussion

This section discusses the perspectives expressed by domain experts and participants involved in the case studies concerning the decision model. It further elaborates the insights gained and observations made during the research, development, and evaluation phases of the decision model. Additionally, this study critically examines the limitations encountered throughout the research process. By presenting these viewpoints, lessons learned, threats of validity and limitations, this section aims to provide a comprehensive understanding of the decision model and its implications within the study context.

8.1 Case studies

We conducted three case studies in different industries to identify feature requirements using the MoSCoW prioritization technique. Several participants expressed their requirements with mostly hard constraints, which resulted in more infeasible solutions. Through discussions, we tried to relaxed some of these constraints by converting a set of hard constraints (Must-Have and Won't-Have) to soft constraints (Should-Have, Could-Have, or None). It is important to note that prioritizing features is a complex task, and decision-makers may not always be aware of the limitations associated with their desired solution. By considering multiple features, we address the limitations, complexity, and compatibility within a multi-cloud environment.

The case studies encompassed organizations of diverse sizes and industries. Notably, a discernible trend emerged wherein larger companies exhibited a higher number of requirements. The prevalent presence of "must-have" requirements across all case studies resulted in a limited number of feasible solutions. Despite subsequent discussions, it was observed that most organizations displayed inflexibility in relaxing these strict constraints.

An interesting outcome of the decision model was the striking similarity between the solutions generated and the anticipated outcomes as perceived by the case study participants. This alignment between the decision model's output and the participants' expectations lent promise to the validity and accuracy of the decision model's results.

8.1.1 CSP features

The framework incorporates a comprehensive set of features that take into account both the business requirements and the organization's in-house knowledge. At first, we will focus on the discussion of the business requirements.

Business requirements

For cloud services, data management emerged as a crucial requirement across all case studies, indicating its status as a must-have feature. However, blockchain technology was not deemed important in the context of the case studies. Additionally, while low-code applications were not considered a primary driver for migrating to the cloud, they were perceived as a desirable feature. The inclusion of mobile functionality was identified as a must-have, although the capability to build applications directly through the cloud provider was not deemed essential. The utilization of IoT technologies varied across industries, suggesting that its relevance is highly industry-specific. In terms of machine learning and AI, the participants recognized the value of these functionalities but indicated that their current usage was limited. Consequently, they were considered as potential future features, aligning with long-term visions. Among the AI functionalities, chatbots and digital assistants were the most commonly utilized. Furthermore, management and governance, media services, migration and transfer, and security were unanimously identified as must-have services when transitioning to the cloud or adopting a multi-cloud environment.

Summarizing the findings from the cloud services, organizations typically require services related to data management, infrastructure, developer tools, management and governance, media, migration and transfer, as well as security in their cloud or multi-cloud implementations.

The inclusion of data center location was considered a crucial requirement due to specific policies and the need for low latency in the case studies. Compliance policies, for instance, mandated that the data center be situated within the Netherlands. Furthermore, the proximity of data centers to the operational location was emphasized as an essential factor in order to minimize latency, which was deemed significant. Additionally, the case studies highlighted the preference for data storage exclusively within the designated data center, although this particular aspect could not be directly incorporated into the decision model. Consequently, it is recommended that discussions regarding data storage location be conducted with the cloud provider during the evaluation of SLAs.

Compliance emerged as a must-have and significant factor in the case studies. It was highlighted that organizations find it advantageous to leverage CSPs to meet compliance standards, as the CSPs themselves ensure compliance and alleviate the burden on organizations to establish and maintain compliance frameworks independently. The adoption of CSPs enables organizations to uphold compliance standards more effectively.

Moreover, the specific compliance standards selected varied depending on the industry in which organizations operated. Certain industries impose more rigorous compliance requirements, necessitating thorough evaluations of CSPs' compliance capabilities by organizations.

Given the industry-specific nature of compliance mandates, it is essential for organizations to diligently assess and verify the compliance offerings of CSPs to ensure alignment with their respective industry-specific requirements.

By relying on CSPs to address compliance concerns, organizations can streamline their compliance efforts, optimize resource allocation, and mitigate compliance-related risks. This underscores the importance of considering and verifying the compliance capabilities of CSPs as a critical aspect of selecting a suitable multi-cloud environment.

The customer ratings, while intriguing, did not significantly differ between the competing cloud providers, and therefore, they were not considered deal-breakers and were deemed less crucial in the context of multi-cloud composition.

The USPs of the cloud providers were regarded as highly interesting and important when seeking specific SaaS offerings desired by the organizations. The experts highlighted that these USPs could be used as a criterion to identify potential providers to be included in the decision model, allowing for an evaluation of compatibility with the organization's requirements and subsequently enabling a comparison of compatibility between different CSPs.

The availability measures provided in the SLAs were perceived as interesting data; however, they were not deemed important enough to significantly influence the selection of CSPs or the decision-making process for multi-cloud environments.

Lastly, the cost indication and cost forecasting feature garnered interest; nevertheless, its relevance was contingent upon the specific case requirements. While the cost indications provided insightful information, the experts emphasized the importance of first assessing the overall suitability of the CSPs with the organization. Subsequently, during the contract establishment phase, the costs could be compared in a case-specific manner. Nonetheless, when organizations conduct their own evaluations of CSPs, the availability of cost indication and forecasting features becomes crucial, enabling them to effectively utilize tools such as TCO calculators.

In-house knowledge

Next, we shall delve into the aspect of in-house knowledge. The inclusion of the "Bring Your Own License" policy was identified as an important consideration in the case studies. The rationale behind this was that bringing licenses to the cloud environment can lead to cost reductions, making it a must-have feature in two of the case studies. In the remaining case study, while the importance of BYOL was acknowledged, it was not categorized as a should-have requirement due to the organization's existing infrastructure and licensing arrangements.

Regarding the choice of OS, they were unanimously considered must-have features, as the organizations relied on specific OS for their operations. This recognition of the importance of operating systems underscores their significance in the cloud environment.

In addition to programming languages, database systems were also recognized as important features in the case studies. The rationale behind this importance aligns with the reasoning applied to programming languages. It was revealed during the discussions that organizations develop expertise in specific database systems and programming languages and adopting new methods or technologies would result in increased costs and complexities associated with migration. Therefore, the selection and compatibility of database systems were considered crucial factors in the decision-making process for organizations opting for a multi-cloud environment.

Another observation emphasizes the notion of vendor lock-in, as organizations tend to rely on specific programming languages and database systems that align with their engagement with a particular CSP, such as Azure in the case of PowerShell. The recognition of the potential for vendor lock-in highlights the need for careful consideration and evaluation of programming languages and database systems to mitigate migration challenges, minimize costs, and maintain operational efficiency in a multi-cloud setup.

Overall, the inclusion of BYOL, operating systems, database systems and programming languages as must-have features in the case studies underscores their significance in the decision-making process for organizations adopting a multi-cloud environment.

Combination enablement

The case study participants found this part of the evaluation really interesting, however not all features were taken into account. API was too technical for the case study participants and was left out of consideration. For container orchestration the need of standardisation was a must have, however only kubernetes and docker were recognized.

The unconsidered API feature suggests that this particular feature may be deemed less crucial when assessing the initial compatibility of a multi-cloud environment.

8.1.2 CSP alternatives

The empirical case studies provided substantial evidence supporting the utility of the decision-making framework in facilitating the comparison of alternative CSPs. However, it was found that the approach to accessing CSPs should be contingent upon the specific organizational requirements. When assessing CSPs for infrastructure-related needs, it becomes imperative to ensure compatibility with various programming languages and cater to all operational needs within the organization. On the other hand, when considering SaaS providers, the level of adherence to all company divisions may not be a strict requirement.

The selected CSPs in the case studies were deemed adequate for accessing major infrastructure providers, as they encompassed significant players in the cloud computing market, such as Azure, AWS, and GCP. The framework demonstrated its versatility in evaluating both SaaS and IaaS options, but it was recognized that the specific requirements must vary based on the extent to which employees utilize the services.

The decision model proved effective for comparing CSPs with regards to infrastructure offerings, as it encompassed a comprehensive range of criteria, ensuring that the selected provider could meet the organization's diverse needs. The assessment of infrastructure providers required careful consideration of compatibility with various programming languages employed within the organization, as well as the capacity to address all operational requirements.

In contrast, when assessing SaaS providers, the decision model could be more flexible, as it may not be necessary for these providers to adhere to all company divisions. Instead, the focus could be on selecting SaaS applications that directly cater to specific business functions or user groups, without requiring a comprehensive fit with the entire organizational structure.

In conclusion, the empirical case studies underscored the significance of the decision model in comparing alternative CSPs. To maximize its effectiveness, the approach to accessing CSPs should be tailored to the specific needs of the organization. For infrastructure-related requirements, the framework must encompass all languages and operational needs, while for SaaS considerations, a more flexible approach may be adopted, focusing on specific business functions. The decision model demonstrated its adaptability for both SaaS and IaaS evaluations, with the extent of employee usage being a determinant factor in shaping the requirements. As organizations continue to navigate the complexities of multi-cloud adoption, the decision-making framework stands as a valuable tool for guiding their selection process and optimizing their cloud service provider choices.

8.1.3 Feasible combination mapping

For partners and combination examples the participant could see given their requirements which partnerships would work with the CSPs which had the best fit with the organisation. This showed which multi-cloud environments proved to work and added value to the decision framework noted by the case study participants. Although the decision model shows a curated short-list of CSPs that are well-aligned with the multi-cloud environment, it is essential to note that further specific requirements need to be established in collaboration with the selected providers to ensure the best fit for the organization's needs.

8.2 Expert interviews

This section provides a comprehensive description of the data analysis process employed for both expert interviews and literature study, which involved a systematic coding procedure to identify relevant topics and concepts. Through this rigorous analysis, the study successfully identified, refined, and enriched the essential features required to enable seamless access to a multi-cloud environment, incorporating insights derived from the interviews and literature review.

Initially, the interviews and systematic literature review primarily focused on identifying quality attributes as relevant factors. However, a notable gap in the literature was the absence of measurable attributes for quality attributes, which this research aimed to address by providing quantifiable metrics(Sun et al., 2014). Although experts confirmed the importance of quality attributes, they also acknowledged the challenge of measuring them. Subsequent interviews revealed additional measurable features, as detailed in Chapter 6. Domain experts emphasized the importance of selecting a CSP that aligns with the organization's in-house knowledge, underscoring the importance of personnel possessing relevant expertise and potential existing linkages between legacy systems and the chosen CSP. In addition, the incorporation of in-house knowledge as a feature group allowed for the consideration of user experiences, such as programming languages and operating systems, thereby addressing the gap in user experiences within the cloud computing domain(Sun et al., 2014).

The popularity of CSPs in a specific region was identified as crucial, particularly in terms of recruitment, with the availability of implementation partners serving as an additional factor to consider. The experts noted that larger CSPs tend to have a greater number of implementation partners and experienced professionals, further highlighting their significance. Although geographical variations in partner availability could not be directly incorporated into the decision model, this aspect could be considered as an additional criterion for organizations.

Moreover, the preference for major CSPs, such as AWS, Azure, and GCP, stemmed from their extensive features and options. This preference was corroborated by the findings from the case studies, where participants extensively utilized features offered by these major providers. Azure's prominence in Europe, driven by the prevalence of Microsoft licenses among organizations, made it an appealing choice as a cloud provider in the region. AWS, on the other hand, was predominantly considered in the United States, while GCP was commonly encountered in startup environments. Despite the variations among providers, they consistently offered innovative services that aligned with industry trends.

The study also explored the link between in-house knowledge and concerns related to complexity. Seamless integration between CSPs and legacy systems was identified as a requirement for achieving efficient infrastructure and successful migration. However, it was recognized that increased infrastructure complexity could result in higher maintenance costs. To mitigate this challenge, the adoption of infrastructure-as-code was suggested as a solution, along with the broader implementation of multi-cloud strategies to mitigate vendor lock-in risks and facilitate the development of contingency plans for potential CSP transitions. Organizations also considered a CSP exit strategy to address availability issues, although this primarily focused on minimizing the impact of downtime due to the significant costs involved.

The decision to adopt a multi-cloud environment within an organization should be supported by a compelling business case that explicitly justifies the need for such an environment. While multi-cloud deployment offers various benefits, the integration challenges and associated costs should be justified by a strong business rationale.

Furthermore, the experts acknowledged the potential influence of compliance regulations and technological advancements on the cloud provider landscape. For example, the introduction of Germany's C5 compliance certification requirement for cloud providers was cited as an instance of how compliance measures can reshape the cloud market.

The developed decision model was highly regarded by the experts, who recognized its value in assessing compatibility and determining the suitability of existing environments. They emphasized that the decision model serves as an effective tool for generating a shortlist of CSPs for further exploration, including detailed evaluations of SLAs.

8.3 Lessons learned

The experts demonstrated a strong interest in the decision model and recognized the significance of the identified features within the context of multi-cloud environments. The findings from the case studies generally aligned with the expert opinions, except for one case study that exhibited unique circumstances specific to that particular case.

Both the expert interviews and the case studies confirmed that the decision model primarily serves as a foundation for selecting CSPs. When considering the adoption of a multi-cloud environment, the decision model proves most valuable in generating a concise list of CSPs that are highly compatible with the organization's requirements. Subsequently, organizations can engage in more detailed discussions regarding SLAs and other contractual aspects, which heavily depend on the specific circumstances of each case.

The existing literature also supports this notion by emphasizing the extensive range of features presented in Table A.2. However, considering all these features comprehensively would be impractical for organizations within a reasonable timeframe. Therefore, based on insights gained from expert interviews and the case studies, certain features such as API, customer ratings, and SLAs were questioned in terms of their importance. On the other hand, the remaining features were consistently deemed important and useful.

To begin the process of identifying the most suitable multi-cloud environment, a company should initially focus on identifying compelling CSPs based on USPs and their specific business case. Subsequently, data should be gathered for all features, excluding API, customer ratings, and SLAs, as they were deemed less critical. By conducting thorough research and gathering requirements for all other features, the decision model can then generate a shortlist of the most suitable CSPs.

Our study aimed to enhance the transparency of CSP selection and address user preferences by identifying relevant features. This endeavor addresses gaps identified in the existing literature, as highlighted by (Sun et al., 2014). Furthermore, it is important to note that the domain of multi-cloud computing has limited research available. Therefore, through our research, we aim to contribute to the advancement of knowledge in the field of multi-cloud computing and address the existing limitations.

Lastly, our framework focuses on identifying the most suitable CSP based on the defined criteria. In cases where a feasible solution cannot be achieved, a multi-cloud environment can be recommended. Throughout the case studies and expert interviews, it was observed that organizations, driven by their business cases, often opt for a single infrastructure while utilizing multiple CSPs for different SaaS applications. The selection of these CSPs is often influenced by their USPs, such as enhanced security features.

In conclusion, the decision model received significant interest from the experts, and its application primarily revolves around the selection of CSPs. When considering the adoption of a multi-cloud environment, the framework serves as a valuable tool for creating a condensed list of CSPs that exhibit high compatibility. Further discussions can then focus on the intricate details of SLAs and other contractual considerations that are specific to each case. The existing literature supports this approach by acknowledging the challenges associated with comprehensively assessing the entire spectrum of features within a limited timeframe.

8.4 Threats to validity

Data for this research endeavor will be collected using a combination of SLR, expert interviews, and case studies. To ensure a robust scientific contribution, it is imperative to evaluate the validity of our findings. In order to accomplish this, we will adopt a methodology proposed by Zhou et al. (Zhou, Jin, Zhang, Li, & Huang, 2016), which examines threats to validity (TTV) in the context of software engineering. By referring to their comprehensive investigation of common threats, as presented in Table 8.1, we will systematically validate our research by addressing each identified threat in a thorough manner.

Common validity	Definition
Construct Validity	This threat focuses on determining the appropriate operational measures for the concepts examined in our study.
Internal Validity	The internal validity shows a causal relationship, where certain conditions to lead to other conditions, which might not be true.
External Validity	External validity matches the domain with the study its findings, so the findings can be generalized.
Conclusion Validity	This validity ensures the reproducibility of the research findings.

Figure 8.1: Definitions of TTV (Zhou et al., 2016)

8.4.1 Construct Validity

The concept of validity plays a crucial role in ensuring that the operational measures employed in our study accurately capture the intended concepts. Throughout our SLR process, several threats to validity emerged. Initially, the hypotheses presented in Chapter 4 were formulated based on our understanding of the cloud domain, which subsequently guided the selection of relevant keywords for the automated search. This raises concerns regarding the comprehensiveness of our research, as it may have overlooked important sources or aspects. Additionally, the process of pruning publications during the SLR could introduce biases.

To mitigate these threats, we strictly adhered to the SLR protocol outlined in Chapter 4. During the data extraction phase, we employed a rating system based on the frequency of occurrences for features, techniques, and models, thereby indicating their relative popularity. However, this approach poses a potential threat, as useful features may be undervalued if they appear less frequently in the literature, leading to their potential under representation in our analysis. However, in the event that any crucial features or aspects might have been overlooked or underrepresented, the expert interviews will serve as a corrective measure.

The expert interviews will serve as a validation mechanism and contribute additional features to enhance the decision model. Throughout the iterative process, novel features may emerge, and their validation levels may vary. To address this potential threat, a validation survey will be administered to the participants upon completion of the thesis, seeking their concurrence with the selected features.

In the context of the case studies, the "MOSCOW" prioritization technique was employed for requirements prioritization due to its inherent simplicity, user-friendliness, and capacity to establish clear priorities. Nonetheless, its simplicity may give rise to certain ambiguities and subjectivities. To alleviate this concern, open discussions were conducted with the participants, encouraging them to express their certainty regarding the identified requirements and elaborate on their perspectives. This approach aimed to enhance the rigor and objectivity of the prioritization process.

8.4.2 Internal Validity

Internal validity holds particular relevance in the context of case studies and expert interviews. The process of selecting participants and formulating interview questions can potentially introduce biases. To mitigate this threat, we will implement a rigorous selection procedure that involves screening participant profiles to ensure diversity and relevance. Additionally, the interviews will follow a semi-structured approach, which minimizes bias arising from excessive preparation and maintains uniformity in the questions posed to participants.

In the context of the SLR, there is a potential for bias during the publication pruning phase. This stage involves filtering out papers that may be perceived as irrelevant to our research objectives. To mitigate this threat, we have taken comprehensive measures to address transparency and document our decision-making process. These details are meticulously recorded in Chapter 4 and in Mendeley data (Bieger, 2023), thereby providing a thorough account of our thoughts and choices throughout the SLR process.

8.4.3 External Validity

The primary focus of this research centers around the domain of cloud computing, with a specific emphasis on the CSS domain. The findings and framework developed in this study hold relevance for organizations seeking to undertake cloud migration initiatives. However, it is important to acknowledge that different industries may possess distinct requirements and considerations, which could potentially limit the generalizability of our framework.

To mitigate this threat, we have adopted a multi-case study approach wherein we will select and analyze multiple organizations spanning various industries. By conducting this cross-industry analysis, we aim to evaluate the usability and effectiveness of our framework across diverse sectors.

Cloud computing services and CSPs have undergone significant transformations over time, leading to potential changes in the applicability of the decision model across different historical periods. To address this concern and contextualize the findings, we have developed a framework that considers the evolving nature of cloud computing services and the dynamic landscape of CSPs. By incorporating a contextual framework and seeking expert validation, we aim to enhance the applicability and transferability of our research outcomes.

Moreover, the cultural and social factors inherent in the participants involved in the case studies and expert interviews could pose limitations on the generalizability of the research findings, particularly when considering that these studies mostly involve European employees and organizations. To address this potential limitation, we have taken steps to engage in discussions with field experts, ensuring the validation of interpretations and confirming the relevance of the findings within broader domains. Additionally, we have transparently acknowledged this limitation in Section 8.5.

During the SLR phase, we encountered difficulty accessing eight papers, which raises concerns regarding the potential exclusion of relevant literature. However, it is noteworthy that the majority of the papers reviewed were accessible, and we believe that the absence of these eight papers did not significantly impact the overall findings and outcomes of our research.

8.4.4 Conclusion Validity

Throughout our research, a key objective was to ensure reproducibility. To facilitate this, we have meticulously documented our entire research protocol for the SLR, providing comprehensive elaboration in Chapter 4. By offering detailed insights into our methodology, data collection procedures, and analysis techniques, we aim to enable future researchers to replicate and build upon our work in the domain of multi-cloud service selection.

Moreover, the comprehensive protocols employed during the expert interviews are provided in Appendix B.1 and B.2. By furnishing these protocols, our objective is to facilitate future researchers in replicating and identifying features for the decision model. The transparency and accessibility of the interview protocols enhance the prospects of further investigations in the domain of multi-cloud adoption, contributing to the advancement of knowledge and the refinement of decision-making processes in this area.

Furthermore, the data we have collected pertaining to CSPs and our research findings will be made publicly available in Mendeley Data(Bieger, 2023). This accessibility will not only contribute to the current state-of-the-art in CSS but will also serve as a valuable resource for future researchers seeking to gain a deeper understanding of the subject matter and replicate our procedures.

8.5 Limitations

It is pertinent to acknowledge several limitations that could impact the findings and conclusions of our research. Firstly, while there exists an extensive body of literature on features and techniques for CSS in single cloud environments, our interviews revealed that the applicability of quality attributes to cloud providers was not clearly addressed in the literature. Consequently, the features included in our framework were primarily derived from the insights provided by domain experts during the interview process, focusing on important features related to quality attributes.

Furthermore, our sample size for expert interviews was limited to 12 participants, which could be perceived as a potential limitation. However, we stopped data collection after achieving a sufficient level of alignment and saturation of information, minimizing the likelihood of major omissions. Nonetheless, it is still possible that certain features may have been overlooked due to the scarcity of literature, but by incorporating participants from diverse backgrounds, industries, and roles, we sought to mitigate this potential limitation.

Another aspect worth noting is the varying interpretations of the term "multi-cloud" within the domain. While it generally refers to the use of multiple public cloud providers, the specific combination of IaaS and SaaS offerings for a multi-cloud environment can differ. Given the vast number of cloud providers offering diverse services, it is challenging to encompass all possible providers in the decision model. To address this, we have integrated USPs to identify potentially relevant providers for organizations. Nevertheless, there is still a possibility that a suitable provider may be overlooked when using the decision model.

The cross-geographical variation in social and cultural aspects may impose constraints on the generalizability of the multi-cloud framework proposed in this thesis. The formulation and adoption of multi-cloud strategies, along with the decision-making processes involved, are subject to diverse social and cultural influences that differ significantly across various regions and nations. While the expert interviews have identified certain features as crucial for all types of organizations, it is crucial to acknowledge that social and cultural factors play a pivotal role in shaping the decisions related to multi-cloud adoption. These factors can result in distinct requirements, priorities, and approaches towards the utilization of multi-cloud solutions in different contexts, warranting careful consideration and contextualization of the proposed framework for broader applicability.

Regarding the case studies, we conducted them across three different industries to evaluate both the generalizability and usability of the decision model. All case studies validated the expected outcomes and alignment with the decision model. While this suggests that the decision model is industry-independent, further exploration is necessary due to the limited number of case studies conducted.

Lastly, it is important to recognize that the data within the decision model should be reevaluated periodically as decision-making criteria and the landscape of cloud providers evolve. This will ensure that the decision model remains up-to-date and avoids reliance on potentially outdated information.

Overall, these limitations should be considered when interpreting the outcomes of our research, and future studies can build upon these findings to address these limitations more comprehensively.

Chapter 9

Conclusion and future work

This thesis presents a comprehensive framework for multi-cloud environments aimed at assisting organizations in the evaluation and selection of suitable cloud service providers (CSPs) based on predefined decision criteria. The framework incorporates a decision model that utilizes multiple features and applies the MoSCoW (Must have, Should have, Could have, and Won't have) requirements prioritization technique. This technique enables the prioritization of requirements based on their relative importance for successful multi-cloud adoption, ensuring that critical requirements receive the highest priority. The assignment of weights to each category (Must have, Should have, Could have) based on their relative importance can be easily accomplished without necessitating complex calculations. Therefore, we employed the Weighted Sum Model (WSM) to calculate the requirements and derive a solution. Ultimately, the decision model facilitates the identification of the most suitable CSPs for an organization's multi-cloud environment.

The adoption of multi-cloud offers numerous advantages, including leveraging the strengths of multiple cloud providers, mitigating the risk of vendor lock-in, optimizing costs, enhancing reliability and redundancy, accessing innovative technologies, and ensuring advanced security and regulatory compliance. Additionally, the utilization of infrastructure as code as a platform enables streamlined application deployment in a multi-cloud environment by eliminating time-consuming infrastructure setup procedures. This approach enhances overall operational efficiency.

To establish a foundational understanding of the cloud domain and identify key features in CSPs, we conducted a systematic literature review. The review encompassed adoption, selection, and migration techniques, as well as relevant features and providers in multi-cloud environments. From the literature, we identified a total of 50 important features, 57 techniques, and 72 CSPs. Considering the limited literature available on multi-cloud, we consulted domain experts to validate the usage of techniques and determine the importance of features and CSPs in the multi-cloud context. Through an iterative process, we developed the decision model, which was subsequently tested using three case studies. The expert interviews and case studies confirmed that the decision model primarily serves as a foundation for selecting CSPs. All case study participants either expressed satisfaction with the outcome, as it provided the same solution they had envisioned, or it aligned with their existing solution. These results demonstrate the effectiveness of the decision model in assisting organizations in identifying suitable multi-cloud environments and evaluating the compatibility of their existing setups. By analyzing a comprehensive list of features, the decision model enables the examination of potential CSPs based on the organization's business requirements, in-house knowledge, and compatibility among providers.

We learned that to initiate the process of identifying the most suitable multi-cloud environment, a company should initially focus on identifying compelling CSPs based on their unique selling propositions (USPs) and their specific business case. When considering the adoption of a multi-cloud environment, the decision model serves as a valuable tool for creating a condensed list of CSPs that exhibit high compatibility. While the decision model provides a suggested best-match selection, organizations must conduct further analysis and address specific contractual issues with the selected CSPs to ensure a proper fit. Therefore, the decision model serves as an initial starting point, offering a shortlist of CSPs that warrant closer examination by the respective organization. The existing literature supports this approach by acknowledging the challenges associated with comprehensively assessing the entire spectrum of features within a limited timeframe.

Additionally, the collected features in the multi-cloud environment, obtained from domain experts, systematic literature review, and document analysis, contribute to a comprehensive overview of the multi-cloud domain. This dataset can be leveraged to address future challenges. The dataset containing the collected data is available in Mendeley data (Bieger, 2023).

In conclusion, this thesis aimed to investigate the development of a decision support framework for multi-cloud service composition. Building upon this framework, a decision model was created that incorporates business requirements, in-house knowledge, and compatibility among providers using MoSCoW prioritization. The requirements were computed using the WSM to assess their suitability. The contributions of this thesis include a comprehensive multi-cloud framework and decision model that enhance the decision-making process for organizations adopting multi-cloud environments. The validity of the decision model was confirmed by its consistency with the outcomes of the case studies. By providing insights into the suitability of CSP and facilitating the exploration of various features, the decision model assists organizations in making informed decisions throughout their multi-cloud journeys.

Considering the limited existing research on multi-cloud environments, our study has identified several promising directions for future research. These directions aim to further enhance our understanding of multi-cloud and explore its various dimensions in greater depth. It would be beneficial to develop a dataset that incorporates automated updates, ensuring the ongoing relevance and accuracy of the decision model in the rapidly evolving CSP landscape (Saha et al., 2021). While our case studies encompassed organizations from three distinct industries, further investigation into industry-specific analyses of multi-cloud environments could be pursued to uncover potential variations and nuances specific to different sectors. However, our current findings do not indicate any significant disparities across industries.

Furthermore, future research endeavors could expand the methodology employed in this study to encompass non-boolean features, such as contractual considerations, which hold significant importance in the selection and adoption of multi-cloud environments. Exploring the impact of these non-boolean features could provide valuable insights for organizations aiming to evaluate and compare CSPs more comprehensively.

Additionally, investigating the typical establishment of multi-cloud environments, considering that experts have indicated it often involves a single infrastructure supporting multiple SaaS applications, would be an intriguing avenue for future research.

Finally, the correlation between company size and the number of requirements observed in our study presents an interesting area for further exploration. Future research could delve into the underlying factors and implications associated with varying requirements based on company size.

Appendix A

Systematic literature review

Deployment model		Delivery model	
PaaS	100	Public	70
IaaS	107	Private	65
SaaS	107	Hybrid	52
		Community	31
		Virtual	2

Table A.1: Deployment and delivery models

Security & privacy	80	Server Location	13
Availability	72	Sustainability	12
service costs	70	Monitoring & testing	12
Reliability	65	Change management	11
Response time	57	Usefulness	9
Performance	53	Certifications	8
Data management	44	Complexity	8
Compliance	44	Contracts	7
Interoperability	42	Business opportunities	7
Scalability	41	Competitive position	7
Throughput	34	Change management	7
Reputation	32	Financial readiness	6
Support	29	Sufficient resources	6
Usability	28	Migration type	6
Tailorability	24	Environment configuration	5
Transparency provider	22	Time to market	5
Flexibility	20	Long-term vision	5
Elasticity	19	Commitmenpait of resources	4
Disaster recovery	18	Training	4
Maintainability	18	Establishing goals	4
Management support	18	Context analyses	4
Adaptability	17	Prior adoptions	3
Portability	17	Cloud design	2
Competibility	15	User feedback	2
Ownership	14		

Table A.2: Features list

TOE	18	NFC	1
DOI	12	PEST	1
TAM	8	PITSR	1
UTAUT	5	DTPB	1
ARTIST	3	IDT	1
SEM-ANN	2	SCT	1
TRA	2	De lone and McLean	1
TPB	2		

Table A.3: Adoption techniques

AHP	43	GRA	4
Fuzzy	35	DEA	4
Topsis	29	WASPAS	3
ANP	17	SWARA	3
VIKOR	14	Outranking	3
Trust based	13	CSMIC	2
ELECTRE	13	TODIM	2
Delphi method	11	COPRAS	2
PROMETHEE	10	SAW	2
MAUT	10	SWA	2
DEMATEL	8	Goal programming	2
BWM	8	Markov chain	2
ISM	6	Requirements based	2
BSC	5	bayesian approach	2
MULTIMOORA	4	Cost based	2
MACBETH	4		

Table A.4: Selection techniques

REMICS	6	SODA	1
SMART	4	SOMA	1
SAE	1	CloudMig	1
SOAD	1	SoSR	1

Table A.5: Migration techniques

Provider	Paas	Saas	Iaas	Public	Private	Hybrid	Community
AWS	X	X	X	X	X	X	X
Azure	X	X	X	X	X	X	X
IBM	X	X	X	X	X	X	X
Google	X	X	X	X	X	X	X
Salesforce	X	X	X	X	X	X	
Oracle	X	X	X	X	X	X	
VMware	X	X	X	X	X	X	
Host gator	X		X	X	X	X	
SAP	X	X	X	X	X	X	
KPN (iS)	X		X		X		
Leaseweb	X		X	X	X	X	
Alibaba	X	X	X	X	X	X	
Heroku	X			X	X		
OpenShift	X			X			
CloudFoundry	X			X	X	X	
DigitalOcean	X	X	X	X	X	X	
Solentive	X	X	X	X	X	X	
eApps	X		X	X	X		
Rackspace	X	X	X	X	X	X	
Cisco webEX	X	X	X	X	X	X	
Linode	X	X	X	X	X	X	
APTEAN	X	X	X	X	X	X	
Ebay		X			X		
DELL VCE		X	X		X	X	
E-builder		X		X	X		
Backup Genie			X		X		
Bluehost			X		X		
Carbonite			X		X		
facebook			X	X			
dropbox			X	X	X	X	
elephant drive			X	X	X		

Table A.6: Providers matched with their delivery and deployment models (1)

Provider	Paas	Saas	Iaas	Public	Private	Hybrid	Community
idrive			X		X		
ipage			X	X			
justhost			X	X			
Justcloud			X		X		
opendrive			X		X		
webhostinghub			X	X			
flexiscale			X	X	X		
OVH			X	X	X		
Interoute/GTT			X	X	X	X	
Apple			X		X		
Openstack			X	X	X		
AT&T			X		X		
Eucalyptus			X		X	X	
Joyent			X		X		
Intel			X	X	X		
Yahoo			X		X		
aruba			X	X	X	X	
HP			X	X	X	X	
Cloud sigma			X	X	X	X	
GMOcloud us			X		X		
Procore			X		X		

Table A.7: Providers matched with their delivery and deployment models (2)

Appendix B

Interviews

1.	Consent for interviewing and recording A brief description of the project and the main goal of the interview
	Difference between hybrid and multi-cloud
2.	Introductory questions
	How long have you been working in Cloud Computing domain (or similar field)?
	What kind of cloud providers have you worked with/ encountered?
	What cloud provider(s) does your organisation use?
3.	Providers
	In what aspect do you think all the different cloud providers differ?
	Do you see a trend within cloud provider selection? any new features or priorities?
	How do you see the future of cloud computing/ providers?
4.	Feature selection
	What kind of features do you think are important to look at when selection a cloud provider?
	How did you choose between cloud providers?
	How did you investigate this?
	Are you using any techniques for feature selection?
5.	Feature evaluation
	Considering features that we have gathered in the SLR, which ones would you say that are the most important?
6.	Multi-cloud
	Have you seen a company using a multi- cloud environment?
	What kind of cloud providers were combined? How did they know they were compatible?
	What makes cloud providers combinable? what are issues
	I want to compare and evaluate the best providers for a company, what would you think drives the decision
7.	Feature validation
	Given all that is discussed, What do you think is most important when selecting cloud providers? business and technical? something missing?
8.	Closing
	What do you think about our work?
	Any thoughts or tips about our work?
	Would you consider using a model for multi-cloud provider decision making
	May we contact you if we have any questions?
	Can we use the name of your company in the scientific paper or do you prefer an anonymous name?
	Do you have any questions or additional feedback?

Figure B.1: Interview protocol phase 1

	Consent for interviewing and recording
1.	A brief description of the project and the main goal of the interview
	Difference between hybrid and multi-cloud
2.	Introductory questions
	How long have you been working in Cloud Computing domain (or similar field)?
	What kind of cloud providers have you worked with/ encountered?
	What cloud provider(s) does your organisation use?
4.	Multi-cloud
	Have you seen a company using a multi- cloud environment?
	What kind of cloud providers were combined? How did they know they were compatible?
	What makes cloud providers combinable? what are issues
	I want to compare and evaluate the best providers for a company, what would you think drives the decision
5.	Framework
	Go through framework
6.	Closing
	What do you think about our work?
	Any thoughts or tips about our work?
	Would you consider using a model for multi-cloud provider decision making
	May we contact you if we have any questions?
	Can we use the name of your company in the scientific paper or do you prefer an anonymous name?
	Do you have any questions or additional feedback?

Figure B.2: Interview protocol phase 2

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