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Enabling factors towards the successful interoperability of cloud platform ecosystems in enterprises

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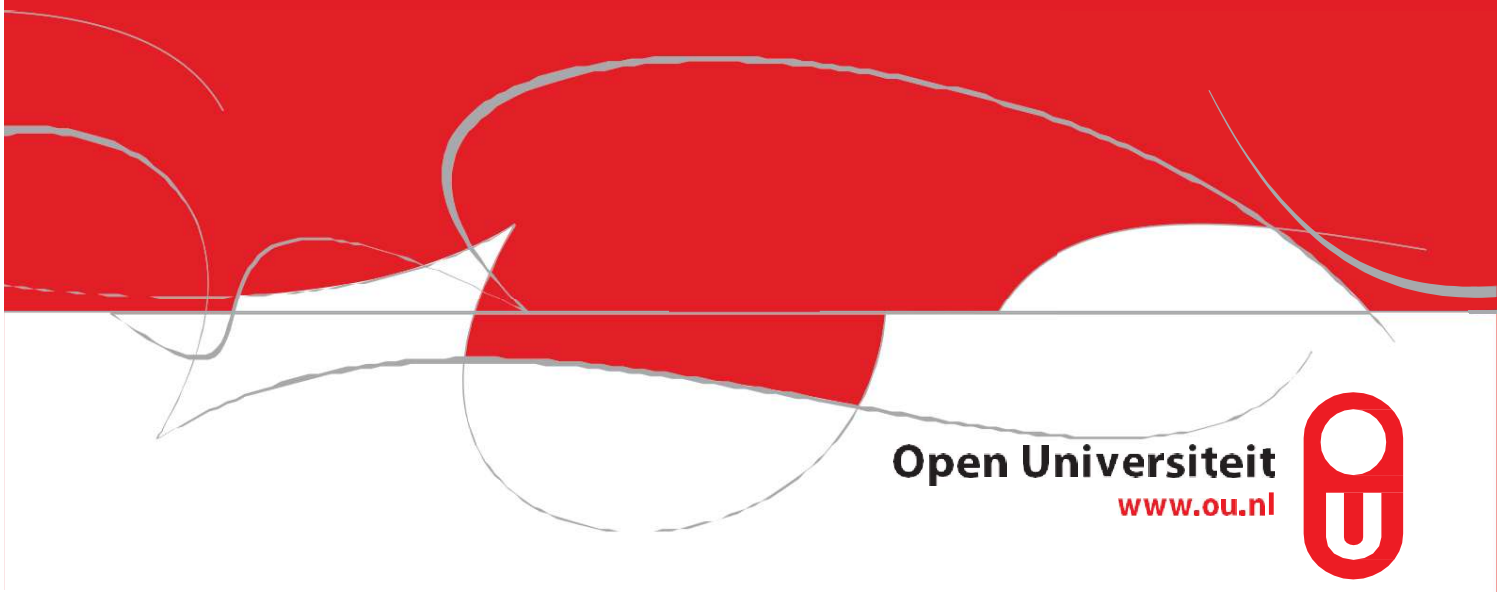

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Enabling factors towards the successful interoperability of cloud platform ecosystems in enterprises

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Abstract

In recent years, companies leverage cloud computing technologies that allow third-party developers to implement complementary applications and customers to quickly deploy these applications forming a cloud platform ecosystem. Although there is a plethora of services deployed in the cloud, single cloud services often failed to answer the clients' evolving and complex requirements and resulted in stronger need for multiple cloud applications to be able to work seamlessly together. This study aims to identify the factors which enable successful interoperability of cloud platform ecosystems in enterprises, on various interoperability levels such as technical interoperability, conceptual level interoperability and organizational level interoperability. This research proposes a framework of enabling factors for interoperability of cloud platform ecosystems, by studying interrelationships between people, process, data and services with cloud interoperability. The development of the framework was conducted in a qualitative holistic single case study at an organization in manufacturing sector in the Netherlands, which is implementing interoperable cloud platform ecosystems. The framework has been evaluated in an empirical study through semi-structured interviews. This study benefits enterprises which leverage the multi-cloud platforms for realizing business requirements, by shedding light on factors enabling the interoperability between multiple cloud platforms.

Key terms

Interoperability, Cloud, Enterprise interoperability, Multi-Cloud applications, Cloud ecosystem

Summary

Use of Cloud Computing services has been influencing the IT landscape. Cloud Computing has gained increased attention among organizations. With such an increasing popularity of cloud computing, a serious challenge that prevents fostering their widespread adoption is that of interoperability. Cloud interoperability refers to the ease of migration and integration of applications and data between different cloud providers. The benefits of interconnected cloud environments for both cloud providers and their clients are numerous and there are essential motivations for cloud interoperability. Interoperability of cloud applications has a huge impact on the cloud adoption in organizations.

Cloud interoperability is a challenging issue and is influenced by both functional and non-functional aspects. As a part of this study, a framework that covers various enabling factors towards the successful interoperability of cloud platform ecosystems in enterprises, was developed. The enabling factors identified in the theoretical framework were empirically validated and refined using information from case organization.

As part of the literature research, 111 articles were assessed. Based on the inclusion and exclusion criteria the total number of articles were narrowed down to nine. Literature research found various enabling factors within different interoperability levels - business, process, service and data. These enabling factors were further categorized into different interoperability dimensions – conceptual, technological and organizational.

The selected case organisation makes use of software applications from two different cloud platform ecosystems and is in the process of implementing a project involving cloud to cloud interoperability of two different platform ecosystems. However, the implementation of second cloud platform ecosystem in the organization was still ongoing at the time of this study and hence there were no interoperability scenarios between the two cloud platform ecosystems available in the organization. However, the knowledge of cloud interoperability existed within the employees and implementation partners of case organization.

Interoperability of business
Enabling factors such as “Avoidance of vendor lock-in”, “Scalability”, “Inter-organizational supply chain in networked enterprises”, which are mentioned in the framework, were positively validated by respondents whereas the enabling factors “regulations” , “Market Platform” , “Aggregator” were not validated in the empirical study. One possible reason why these elements were not validated in the empirical study could be because they are not yet popular in the industry or not used in the case organization.

Interoperability of processes
Enabling factors such as “Distributed business processes and business-to-business integration”, “Cloud modelling framework and cloud modelling languages”, “Microservices” were validated while the enabling factors “Alignment of cross organizational business process” and “Cloud Computing Standardization Organizations” mentioned in the framework were not validated. The reason for discrepancy in the results of literature review and empirical study for the enabling factor “Alignment of cross organizational business process” can be justified by the fact this element is supporting interoperability in specific situations but not in general as a whole and it should be taken case by case for each individual organisation.

Interoperability of services

Enabling factors "Service oriented architecture", "Open libraries", "Service Level agreement" were validated by most of the respondents. Enabling factors "Model-driven approach", "Cloud standardization projects", Service broker", "Service description languages" and "Agents for the service description and discovery" were not validated as enabling factors during empirical study. A possible reason for not validating these factors could be that these elements are more related to "platform owner" of the cloud platform ecosystem and should have been validated by someone from "platform owner" organization. Nobody from the platform owner organization was part of research population in the empirical study. In order to have a conclusive result, further research is recommended.

Interoperability of data

"Trust model", which ensures the security of cloud entities in cross-cloud applications was one of the enabling factors mentioned in the theoretical framework. This was positively validated by all the respondents. The enabling factor "Security" was validated by all the respondents and was deemed as an important enabling factor. The enabling factor "Standardized APIs and data models" was also validated by most of the respondents. The enabling factor "Information interoperability" was not validated by respondents. "Information interoperability" seems to be more related to the area of business intelligence which is a specialized area and further research is needed to provide a conclusive answer about the impact of this enabling factor.

During the empirical study, it was evident that there is discrepancy between the results of literature search and empirical study. The elements of the theoretical framework, which were not conclusively validated in empirical study, were removed from the final practical framework. Additional research is required to clarify the inconclusive results of some of the enabling factors.

Topics such as "cloud licensing model", "change management of cloud applications" and "governance of interoperable clouds" are some of the enabling factors mentioned as missing in the framework by respondents. In addition, "agility to business", "digital transformation", "competitive edge"," cost-benefit analysis" and "innovation" are mentioned as possible enabling factors by the respondents. These additional elements proposed by respondents need to be added to the framework in the form of a second design-evaluation loop according to the Design Science research methodology. However, this was not conducted due to the limited timeframe of this research.

Final practical framework covered a lot of areas of enterprise interoperability and can be used as a checklist by organization considering cloud interoperability projects, to co-ordinate discussion among various stakeholders. Once the framework is refined based on further research, it can be used by enterprises which are using cloud applications or considering the move to cloud, to critically think about the possibilities of cloud interoperability and to initiate the discussion on various topics related to factors enabling the cloud interoperability.

Contents

1. Introduction

1.1. Background

Cloud computing services is an information technology service model where computing services (both hardware and software) are delivered on-demand to customers over a network in a self-service fashion, independent of device and location(Marston, Li, Bandyopadhyay, Zhang, & Ghalsasi, 2011). National Institute of Standards and Technology (NIST) outlines three service layers to render cloud computing capabilities: Infrastructure-as-a-Service (IaaS), Platform-as-a-Service (PaaS) and Software-as-a-Service (SaaS). Although, there was a plethora of services deployed in the cloud, single cloud services often failed to answer the clients evolving and complex requirements, and resulted in stronger need for multiple cloud platforms to be able to work seamlessly together(Bouzerzour, Ghazouani, & Slimani, 2020). However most new cloud providers propose their own solutions and proprietary interfaces for access to resources and services. This heterogeneity is a crucial problem as it raises barriers to the path of the ubiquitous cloud realization(Toosi, Calheiros, & Buyya, 2014).Cloud interoperability represents the ability of heterogeneous systems, which are deployed in the same cloud or in multiple clouds, to communicate together. The ability to make the components to work in independent cloud with minimal or null user effort is called interoperability(Zhang, Wu, & Cheung, 2013). Benefits of an interconnected cloud environment for both cloud providers and their clients are numerous, and there are essential motivations for cloud interoperability such as avoiding vendor lock-in, scalability, availability, low-access latency, and energy efficiency(Toosi et al., 2014). Interoperable clouds promisingly represent the trend of cloud technologies, since they better fulfill the ultimate goal of the cloud computing paradigm, in providing global-scale, “unlimited” computing utilities with unified access interfaces(Rochwerger et al., 2009).The importance of cloud interoperability has been highlighted by both the industry and the academia.

Mezgár(Mezgár & Rauschecker, 2014) mentions that interoperability has huge impact on the cloud adoption in organizations. This study aims to identify factors which enable interoperability of cloud platform ecosystems in organization, on various interoperability levels such as technical level interoperability, business level interoperability and organizational level interoperability.

1.2. Exploration of the topic

1.2.1. Interoperability in cloud computing

The terms interoperability, compatibility and portability are closely related terms in cloud computing and may often be confused. Cohen clarifies the similarities and the differences among these terms in an attempt to exemplify and differentiate them(Cohen, 2009). Cloud interoperability refers to the ease of migration and integration of applications and data between different providers’ clouds(Dowell, Barreto, Michael, & Shing, 2011). Cloud compatibility means that the application and data can work in the same way regardless of the cloud provider, whereas cloud portability is the ability of data and application components to be easily moved and reused regardless of the choice of cloud provider, operating system, storage format or APIs. As stated by Toosi(Toosi et al., 2014),if cloud interoperability requires cloud providers to adopt and implement standard interfaces, protocols, formats, and architectural components that facilitate collaboration, it is called provider-centric interoperability. Bouzerzour (Bouzerzour et al., 2020) mentions that Provider-centric interoperability includes Federated cloud and Hybrid cloud. Federated cloud are a set of clouds, which are interconnected voluntarily in the aim of sharing their resources to overcome resources limitation in one cloud by

exploiting the unused resources of another cloud. Hybrid cloud represents the partnership between a private cloud and a public cloud for load balancing at peak moments.

In client-centric interoperability, interoperability is not supported by cloud providers and cloud customers are required to initiate it by themselves or via third-party brokers. This kind of interoperability does not require prior business agreement among cloud providers and allows multiple cloud scenarios without adoption of common interfaces and protocols or with minimal adoption of the same(Toosi et al., 2014). Client-centric interoperability includes Multi-cloud and Cloud broker(Bouzerzour et al., 2020). Multi-cloud are different clouds, which are coordinated and utilized by an end-user or a service to meet certain requirement. Cloud broker is an entity, which acts as a mediator between cloud consumer and multiple cloud providers. It negotiates the best cloud offers in behalf of the cloud consumer as it integrates a set of services and it uses multiple cloud resources

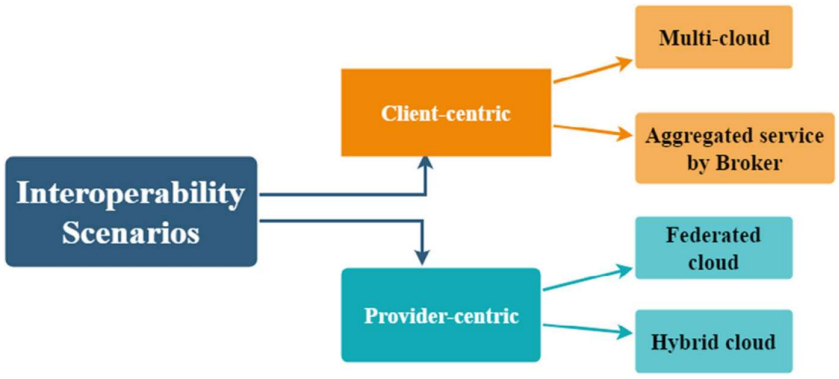

Fig 1: Cloud interoperability scenarios(Bouzerzour et al., 2020)

If interconnection happens between clouds at different levels of cloud stack layers ,for example, a PaaS and IaaS provider, it is called delegation or vertical federation. But if interconnection between clouds happens at the same layer (e.g., IaaS to IaaS), it is called horizontal federation.(Toosi et al., 2014).

1.2.2. Cloud platform ecosystem

In general, digital platforms (e.g., iOS, Android) can be defined as a technological foundation upon which additional complementary products or services can be developed(Gawer & Cusumano, 2014; Zutshi, Grilo, & Nodehi, 2021). Typically, the platform owner, together with third-party developers of complementary products, or services and end-users, form a platform ecosystem(Zutshi et al., 2021). On an abstract level, platforms describe the notion of providing a technological system that acts as a foundation upon which other firms can develop complementary products, technologies or services(Yoo, Boland, Lyytinen, & Majchrzak, 2012). Hein (Hein et al., 2020) remarks that 'a digital platform ecosystem comprises a platform owner that implements governance mechanisms to facilitate value-creating mechanisms on a digital platform between the platform owner and an ecosystem of autonomous complementors and consumers'. Software company SAP, which has a digital platform ecosystems with more than 13,000 partners, has stated, "reaching our full potential depends on how well we enable our partners, providing them with [the] tools they need to accelerate growth and exceed customer expectations in an increasingly complex world."("SAP Partner Edge," 2017). In recent years, companies across industries have started to build platform ecosystems to leverage broad networks of third-party developers for value co-creation(Ceccagnoli, Forman, Huang, & Wu, 2013; Förderer & Langer, 2018; Sandberg, Holmström, & Lyytinen, 2020) These companies

leverage cloud computing technologies that allow third-party developers to implement complementary applications and customers to quickly deploy these applications (Lawton, 2008) forming a cloud platform ecosystem

1.2.3. Enterprise interoperability

An Enterprise is defined as “an organization designed to provide goods, services, or both to consumers." The main ingredients of such a system are Infrastructures, Data, Processes, Policies and People(Koussouris, Lampathaki, Mouzakitis, Charalabidis, & Psarras, 2011).In the context of networked enterprises, interoperability refers to the ability of interactions (exchange of information and services) between enterprise systems. Interoperability is considered as significant if the interactions can take place at least on three different levels: data, services and processes, with a semantics defined in a given business context.

Two basic dimensions of the enterprise interoperability are discussed in the enterprise interoperability framework (two basic dimensions) proposed by INTEROP Network of Excellence(Chen, Doumeingts, & Vernadat, 2008).They are (i) enterprise dimension and (ii) interoperability dimensions.

barriers / levels	CONCEPTUAL	TECHNOLOGICAL	ORGANISATIONAL
BUSINESS			
PROCESS			
SERVICE			
DATA			

Fig 2: Two basic dimensions of the enterprise interoperability proposed by INTEROP Network of Excellence

Enterprise dimensions

As per INTEROP NoE, three categories of enterprise dimensions are identified as follows:

Conceptual: concerned with the syntactic and semantic differences of information to be exchanged.

Technological: concerned with the incompatibility of information technologies (architecture and platforms, infrastructure etc.)

Organizational: concerned with the definition of responsibility (who is responsible for what?) and authority (who is authorized to do what?) as well as the incompatibility of organization structures (matrix vs. hierarchical ones, for example).

Interoperability dimensions

Interoperations can take place at the various interoperability levels as follows :

The interoperability of data: The interoperability of data deals with finding and sharing information from heterogeneous data sources, and which can moreover reside on different machines under different operating systems and data base management systems.

The interoperability of services: It is concerned with identifying, composing and making various applications function together (designed and implemented independently).
The interoperability of processes: The aim is to make various business processes work together: a process defines the sequence of the services (functions) according to some specific needs of a company.
The interoperability of business: It refers to working in a harmonized way at the level of organization and company

1.3. Problem statement

Cloud interoperability is a challenging issue and requires substantial efforts to overcome the existing obstacles such as vendor lock-in and security(Kaur, Sharma, & Kahlon, 2017).Researchers in both the industry and the academia have been working on projects to enable interoperation among clouds, from both the cloud provider's and user's perspectives. Various *enabling factors* for interoperability are proposed by researchers. For example, Petcu (Petcu, 2011; Petcu & Vasilakos, 2014) proposes "Open APIs, Open protocols, Standards, Layers of abstractions, Semantic repositories, and Domain specific languages" as a set of enabling factors for achieving cloud interoperability. Di Martino (Di Martino, 2014) suggests "Model-Based Approaches, Multi-agent Systems, Cloud Patterns, Semantic Models, Open Source Application Programming, Interfaces and Platforms" as another set of enabling factors for achieving service interoperability in cloud platforms. However, majority of these enabling factors emphasize the technical aspect of cloud interoperability and try to surpass in specific facets of interoperability. Kaur (Kaur et al., 2017) states that the most common and obvious solution for interoperability and portability is the adoption of standards by global providers. But far from being adopted, the standards have not been fully embraced by global providers(Kaur et al., 2017). Thus, there is a limited trace of agreement and completeness among existing projects and researches on enabling factors for solving cloud interoperability challenges. As pointed out by Nodehi (Nodehi, Ghimire, Jardim-Goncalves, & Grilo, 2013), there is still no implicit solution to promote cloud Interoperability. A holistic perspective on various factors which enable cloud interoperability in enterprises, is needed for supporting cloud adoption in organizations.

1.4. Research objective and questions

The objective of this research is to identify and validate various factors enabling the interoperability of cloud ecosystem in enterprises by answering the following research question:

What are the factors enabling the interoperability of cloud platform ecosystems in enterprises?

The objective of the research can be achieved using the following sub questions:

- Sub question 1: What are the enabling factors found in the literature, regarding the interoperability of the cloud platform ecosystems?
- Sub question 2: How can these enabling factors be integrated into a theoretical framework, which covers various interoperability concerns in enterprises?
- Sub question 3: How can the enabling factors identified in the theoretical framework be empirically validated using information from case organization?
- Sub question 4: Which of the validated enabling factors are most impactful in practice (i.e., to rank them in terms of relevance, importance)?

- Sub question 5: How can the identified factors influencing interoperability in cloud ecosystems be refined with empirical information?

Research approach sub question 1: By performing a literature research, various enabling factors supporting cloud interoperability will be identified. Different interoperability concerns in enterprises will also be identified as part of literature research.
Research approach sub question 2: By performing data synthesis of scientific articles, useful information will be evaluated and extracted to create a theoretical framework which covers various enabling factors supporting cloud interoperability, mapped to different interoperability concerns in enterprises.
Research approach sub questions 3, 4 and 5 : The findings of the theoretical framework will be validated, adjusted and if necessary, complemented during the empirical part of this research.

1.5. Motivation/relevance

As the adoption of cloud as the main technology for provisioning of infrastructure, platform, and service for users grows continually, the need to aggregate services and functionalities from different providers arises, that motivates cloud interoperability and the mechanisms and technologies enabling it(Toosi et al., 2014). Cloud interoperability makes cloud services capable of working together and develops the ability of multiple clouds to support cross-cloud applications(Bernstein, Ludvigson, Sankar, Diamond, & Morrow, 2009). Cloud interoperability enables enterprises to develop applications which may be distributed across two or more providers or to migrate some or all of a set of existing services to a new provider(Toosi et al., 2014). This study aims to benefit enterprises which leverage the multi-cloud platforms for realizing business requirements, by shedding light on factors enabling the interoperability between multiple cloud platforms and studying interrelationships between people, process, data, services etc with cloud interoperability and cloud computing ecosystem. This study also helps enterprises with cloud ecosystem and business applications which are currently strangled in silos, to critically think about the possibilities of cloud interoperability.

1.6. Main lines of approach

In this chapter an introduction is provided. In the next chapter, identification, analysis and synthesis of the extant literature on interoperability factors of cloud platforms will be done to find the work that already has been done in this field. A new theoretical model that will help in answering the theoretical research question will be developed in chapter 2. Chapter 3 presents a methodology for the empirical research plan. chapter 4 presents the results of the empirical research and chapter 5 presents the discussion, and conclusions.

2. Theoretical framework

In this section, a literature review is performed on the existing theory concerning the research problem and a theoretical framework of enabling factors for interoperability between different cloud platform ecosystems is established based on prior literature. This chapter presents the approach, implementation, results and conclusion of the literature review.

2.1. Research approach

We will use Systematic Literature Review (SLR) to develop the theoretical framework because SLR uses a comprehensive pre-planned strategy for locating, critically appraising, analysing and synthesising

existing research that is pertinent to a clearly formulated research question to allow conclusions to be reached about what is known (Saunders, Lewis, & Thornhill, 2007). In this literature review we aim to answer the following questions:

- Sub question 1: What are the enabling factors found in the literature, regarding the interoperability of the cloud platform ecosystems?
- Sub question 2: How can these enabling factors be integrated into a theoretical framework, which covers various interoperability concerns in enterprises?

The methodology described by (Saunders et al., 2007) is used to complete this review. The following steps are taken as part of SLR:

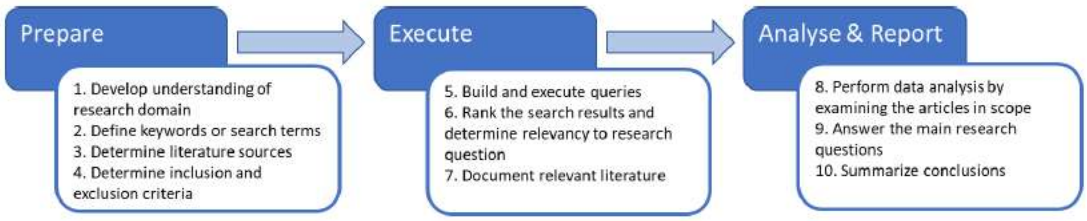

Fig 3: SLR methodology described by (Saunders et al., 2007)

Keywords and search string

Finding an answer to the research questions includes selecting appropriate information resources by executing a search strategy. "Building blocks" approach is employed for the search strategy, where main facets or concept groups of the research problem are systematically combined with Boolean operators to search for the most relevant articles. Based on the research question, an initial set of keywords are used to construct the search query. Simple search using the keywords “Interoperability” and “Cloud” resulted in a large number of hits, where most of the articles are very technical in nature focussing on specific technical issues in interoperability. So synonyms for “Interoperability” and “Cloud” are also used as search terms in making the search query.

The keywords which are eventually used for creating search query are as mentioned in Table 1.

	Key terms (AND)	
	Interoperability	**Cloud**
Related Terms (OR)	Enterprise interoperability	Multi-Cloud applications
		Cloud architecture
		Cloud ecosystem

Table 1: Key terms and synonyms for search strategy

The goal of the search strategy is not to retrieve everything – it is to retrieve everything of relevance to the research questions, while leaving behind the irrelevant(Popay et al., 2006).An initial query was created based on the search terms in Table 1. The query was run and the results were examined to find relevant items. The query was then modified to improve the results. This process of “revise and

re-run" of the query was continued until further modifications produced no improvements. Search query which was finally used is as below :

((TitleCombined:(interoperability)) OR (Abstract:(Multi-Cloud Applications))) AND
((TitleCombined:(interoperability)) OR (Abstract:(cloud architecture))) AND
((TitleCombined:(Interoperability)) OR (Abstract:(enterprise interoperability))) AND
((TitleCombined:(Interoperability)) OR (Abstract:(Cloud ecosystem))) AND (TitleCombined:(cloud))

Searches are performed on the Open University Library which covers many well-known databases, such as Ebscohost, JSTOR, Web of Science, etc

In order to search for primary studies, records are screened to ensure that the best available publications are reviewed. The PRISMA flowchart (Moher, Liberati, Tetzlaff, Altman, & Group, 2009) is used as the selection strategy to reduce the number of search engine results until a final collection of articles was chosen as the final set.

Inclusion and exclusion criteria
A set of inclusion and exclusion criteria are established for conducting the screening.

The inclusion criteria are as follows :
1. Publications are written in English
2. Scientific discipline should be related to computer Science or software engineering
3. The article is focussed on Cloud platform ecosystem

The exclusion criteria are as follows:
1. Studies that are too technical and detailed
2. Studies whose main topic is not about interoperability

Data selection
In the first step, the search query is executed on the digital library provided by OU to search for the articles and the inclusion criteria 1 and 2 are applied. In the second step the results are checked based on duplicates of the articles. The third step is to select articles, based on reading the abstract. This step is necessary in order to provide articles which are being used for further analysis. For this step inclusion criteria 3 and exclusion criteria 2 are applied. In the fourth step, the results are filtered based on exclusion criteria 1 by manually screening through the article on a high level, to filter out articles which are focusing only on specific technical aspects of cloud interoperability or are dealing with proprietary cloud applications. The final step is to select articles, based on reading the article. This step is necessary in order to provide articles that are being used to extract data from. Backward snowballing(Thomé, Scavarda, & Scavarda, 2016) is performed on the set of resulting articles to find related articles to provide different insights.

Data extraction and synthesis
Once we have selected the scientific literature for our research, we will have to evaluate it and extract useful information. This is done according to the systematic and reliable system based on the method of Saunders(Saunders et al., 2007).Review questions are an important method to extract information in a literature review, as the specific questions can be directly or indirectly linked to the research objective(Saunders et al., 2007). A template for review questions is mentioned in Appendix D.For data

extraction, it is important to define interoperability research domains and the scope of interoperability domains to extract relevant information. INTEROP NoE framework defines the research domain of enterprise interoperability and help to identify and structure the knowledge of the domain.(Chen et al., 2008). Hence this framework is used as a basis for performing data extraction, to create a conceptual framework for this study. INTEROP NoE framework categorizes interoperation concerns into different levels of the enterprise namely: data, service, process and business, which is further structured into different barrier categories such as conceptual, technological and organizational barriers. Based on this template, the coding for enabling factors will be performed on the themes of business, process, service and data. These enabling factors for cloud platform interoperability are further categorized into conceptual, technical and organizational layers, in line with the barrier categories mentioned in INTEROP NoE framework . In addition, one additional row is included in the extraction template to include extra aspect which may not be covered in the INTEROP NoE framework. Data extraction will be performed for each selected paper. The results of data extraction are merged into a Thematic Analysis Grid (TAG), as suggested by Saunders (Saunders et al., 2007) to perform data synthesis. Saunders(Saunders et al., 2007) notes that the process of identifying themes, setting up the grid, and finally concluding the TAG is an iterative process that requires us to reread the articles multiple times, and revising the grid in each iteration. The use of the Thematic Analysis Grid for data synthesis, includes below steps(Saunders et al., 2007):

- Identify potential themes from the initial reading of all articles
- Re-read all articles, add a row to the grid and make brief notes under the themes
- Add or remove new themes if necessary
- Look for emerging patterns across the themes

Each of the selected articles for data extraction are processed one by one, following the steps above to complete TAG.

Reliability and validity

For our literature research, construct validity is ensured by a clearly specified research question that should lead to a definition of study aim and objectives that set out the construct. The use of a review template enforces a review procedure(Saunders et al., 2007) which increases the construct validity. To further improve the construct validity, inclusion and exclusion criteria are defined.

By thoroughly assessing the literature found out using the search string, in a structured way with the help of literature review template, internal validity is improved. In order to ensure external validity, it should be possible to generalize the findings of this study. Since a single case study is performed as part of this thesis, there is a limitation to the extend which the findings of this study can be generalized.

In order to minimize the research bias, a researcher should not allow her or his own subjective view or disposition to get in the way of literature search and literature review. We ensure this by trying to observe our research as we were a detached researcher, focusing on the logic of the research, as advised by Saunders(Saunders et al., 2007)

2.2. Implementation

We executed our search and identified 115 articles of which four were duplicates. Remaining 111 articles were reviewed based on our inclusion and exclusion criteria (see Appendix B). Out of 111 articles, 7 were found useful for our research. Another 2 articles were included as part of backward snowballing. Appendix D contains the Literature review forms and Data extraction forms.

2.3. Results and conclusions

We performed our data synthesis on the themes of business, process, service and data, with further categorization into conceptual, technical and organizational layers. Data extraction of the articles revealed a variety of enabling factors contributing to the interoperability of cloud platform ecosystems. Some of the factors like vendor lock-in avoidance, cloud interoperability standards, security and trust model are recurring themes appearing in multiple articles, while other factors are found to be specific to articles.As mentioned in section 2.1, the data extraction template contained an extra dimension to capture the findings which may not be covered in the INTEROP NoE framework. This extra dimension revealed some interesting findings related to the reason behind lack of interoperable cloud solutions and also regarding some of the factors behind the unwillingness of organizations to adopt cloud applications. These findings are mentioned under the section “general findings” below. The results of the data synthesis are organized into interoperability of business, interoperability of process, interoperability of services and interoperability and data. This section will elaborate on our findings and will conclude with a proposed conceptual framework for enabling factors for cloud platform ecosystem interoperability in enterprises.

Details of the results of literature search is elaborated in Appendix F.

A Theoretical framework of “Enabling factors for cloud interoperability in Enterprises” is provided below in Table 2:

Interoperability dimensions	Interoperability levels	Enabling factors	Description	Reference
conceptual	Business	• Vendor lock-in avoidance • Scalability • Regulations • Inter-organizational supply chain in networked enterprises	**Vendor lock-in avoidance** - If interoperability is enabled , the cloud users can easily choose between providers for better Quality of Service (QoS) and cost. **Scalability** - Collaborations between providers for additional computation and storage capabilities can act as an enabler for interoperability **Regulations** - Lack of interoperability is an acquainted problem within the meaning of EU competition law. Any behaviour on the part of a dominant cloud provider that contains an exclusionary element (e.g., refusal to deal,exclusive dealing, tying) might be construed as violating EU competition law **Inter-organizational supply chain in networked enterprises** - Enterprise architectures like that of collaborative enterprise basically consists of a flexible network of co-operating autonomous entities collaborating with each other. Enhanced focus has to be taken on interoperability of connected clouds in these architectures.	(Mezgár, I.,2020) (Bouzerzour, N.E.H.,2020) (Kaur, K.,2017) (Toosi, A. N.,2011) (Ünver, M. B.,2019) (Petcu, D.,2011)
	Process	• Alignment of cross organizational business process • Supporting distributed business process	**Alignment of cross organizational business process** - If diverse business processes across different clouds in organization are able to work together, it can act as an enabler for cloud interoperability. **Supporting distributed business process** - The need to support business process which are distributed in nature, involving business processes in cloud of other organizations that are exposed as services, can enable cloud interoperability.	(Mezgár, I.,2020)
	Service	• Model-driven approach • Cloud standardization projects • Service oriented architecture	**Model-driven approaches** - Model-driven approach for the design and execution of applications on multiple clouds can enable service interoperability between cloud platforms. **Cloud standardization projects** - standards for interoperability (e.g. example, adhering to published interface standards) can enable interoperability. **Service oriented architecture** - SOA is an integration architectural style and an enterprise-wide concept. It enables existing applications to be exposed over loosely-coupled interfaces to support interoperability.	(Bouzerzour, N.E.H.,2020) (Kaur, K.,2017) (Toosi, A. N.,2011)
	Data	• Information interoperability • Platform-independent database abstraction layer • Data Portability • Trust model in cross-clouds applications	**Information interoperability** - If data level interoperability is enabled, information can be seamlessly shared between applications hosted in different clouds. **Platform-independent database abstraction layer** - platform-independent database abstraction layer can enable Data level interoperability **Data Portability** - Inorder for interconnected cloud environments to allow users to easily move their data from one cloud to another for avoiding data lock-in, data level interoperability needs to be enabled using standard metadata and data formats **Trust model in cross-clouds applications** - Trust model which ensures the security of cloud	(Mezgár, I.,2020) (Bouzerzour, N.E.H.,2020) (Toosi, A. N.,2011) (Li, W.,2009)

			entities in cross-clouds applications is the most important means to improve security and enable interoperability of current heterogeneous independent cloud platforms.	
Technological	Business	• Market Platform • Aggregator	**Market Platform** - The market platform represents a marketplace where various cloud computing services of different roles are offered. The main objective of the market platform is to bring customers and service providers together **Aggregator** - With cloud computing a large number of small and modular services arose, creating the opportunity to aggregate these services into value-added, complex solutions for certain needs. This aggregation of services is accomplished by aggregators	(Oberle, K.,2010)
	Process	• Cloud modelling framework and cloud modelling languages • Microservices	**Cloud modelling framework and cloud modelling languages** - Cloud modelling language is a domain-specific modeling language (DSML) for modeling the provisioning and deployment of multicloud systems at design-time.Cloud modelling framework is a tool for the provisioning, deployment, and adaptation of applications in multicloud. **Microservices** - An application development approach, in which an application is developed as a group of small modular services that communicated with each other.	(Bouzerzour, N.E.H.,2020)
	Service	• Middleware • Service broker • Service description languages • Agents for the service description and discovery • Open libraries	**Middleware** - A software layer that provides homogenous interfaces that hide the heterogeneities of hardware and protocols to enable the interoperability and the portability of heterogeneous applications **Service broker** - Service broker which translates messages between different cloud interfaces **Service description languages** - Service description languages enables the description of services functionalities, properties, and capabilities. **Agents for the service description and discovery** - enable transparent interoperability between cloud services **Open libraries and Open services** - Open libraries and Open services rely on the use of abstraction layers and adapter to enable interoperability	(Bouzerzour, N.E.H.,2020) (Toosi, A. N.,2011) (Kaur, K.,2017)
	Data	• Semantic technologies • Standardized APIs and data models • Cloud Data Management Interface(CDMI) • Security	**Semantic technologies** - Semantic technologies facilitate the exchange and interpretation of data between services to enable interoperability **Standardized APIs and data models** - Standardized APIs and data models support in achieving semantic interoperability and are fundamental approaches of various cloud standards for interoperability **Cloud data management interface (CDMI)** - CDMI is a standard that targets storage clouds and it allows standardized access and interoperation. CDMI also enables the migration of the data from one provider to another. **Security** - Important security topics for cloud interoperability include authentication, authorization, accounting and encryption.	(Bouzerzour, N.E.H.,2020) (Kaur, K.,2017) (Zhang, Z.,2013)

Organizational	Business	• Provider-centric interoperability and client-centric interoperability	**Provider-centric interoperability and client-centric interoperability** - Client-centric interoperability gives the clients control over their workloads and a wider range of service choices. Provider-centric interoperability allows the providers to collaborate.	(Toosi, A. N.,2011) (Bouzerzour, N.E.H.,2020)
	Process	• Cloud Computing standardization Organizations	**Cloud Computing Standardization Organizations** - There are many groups and initiatives that are working on cloud computing standards.Standards developing organization (SDO), which are technically involved in developing and publishing standards for cloud computing and cloud interoperability.Standards-setting organization (SSO), work toward promoting the adoption of emerging technologies, typically without the intention of developing their own standards. Cloud standards enable cloud interoperability.	(Kaur, K.,2017) (Toosi, A. N.,2011)
	Service	• Service Level agreement	**Service Level agreement** - Cloud providers define a service-level agreement (SLA) to specify what they guarantee.SLA is a contract that describes a service and, most importantly, sets the expected service-level objectives (QoS expectations). Service level objectives (SLOs) are the core components of a SLA, which are quality-of service measurements for the performance of the service provider. In a scenario where a customer wants to change its cloud provider, the SLOs should be made consistent in order to compare the old SLA with a new one.	(Toosi, A. N.,2011)
	Data	• Data liberation	**Data liberation** - Data liberation makes it easier for the user to move data in and out of cloud. Data liberation effort focuses specifically on tools and methods that allow users to export any data they create and import into another service or competing products	(Toosi, A. N.,2011)

Table 2: Theoretical framework of “Enabling factors for cloud interoperability in Enterprises”

2.4. Objective of the follow-up research

The literature research gives us valuable insight into various factors enabling interoperability in cloud platform ecosystems in organizations. Since interoperability has huge impact on the cloud adoption in organizations(Mezgár & Rauschecker, 2014), our objective of the follow-up research is to empirically validate the relevancy of the framework in a real-life setting and possibly refine it. We are looking for confirmation of the relevancy of the framework as well as the reasoning for it and suggestions for improvement.

3. Methodology

This section describes the details of the empirical research to be carried out to validate the theoretical framework developed in section 2.3. As part of this empirical research below sub questions will be answered :

- Sub question 3: How can the enabling factors identified in the theoretical framework be empirically validated using information from case organization?
- Sub question 4: Which of the validated enabling factors are most impactful in practice (i.e., to rank them in terms of relevance, importance)?
- Sub question 5: How can the identified factors influencing interoperability in cloud ecosystems be refined with empirical information?

Design-science research paradigm is used as the research approach for conducting this empirical research because it is proactive with respect to technology. It focuses on creating and evaluating innovative IT artifacts that enable organizations to address important information-related tasks(Hevner, March, Park, & Ram, 2004). Design Science Research Method (DSRM) introduced by Peffers (Peffers, Tuunanen, Rothenberger, & Chatterjee, 2007) is a methodology that incorporates principles, practices, and procedures needed to execute DSR. DSRM process is followed for this research as it has been used to research information systems focused on the creation of successful models. DSRM process has six activities and they have been employed during various stages of this research as mentioned in table 3

DSRM activity	Activity Description in this research	Corresponding chapter in this research
Problem identification and motivation	Define problem	Section 1.1 to 1.4
Define the objectives for a solution	Infer the objectives of a solution	Section 1.5 to 2.2
Design and development	Theoretical framework	Section 2 and 3
Demonstration	Results of the empirical research.	Section 4
Evaluation	Discussion and reflection	Section 5
Communication	Report and present	Thesis document

Table 3: DSRM process employed during various stages of this research

3.1. Conceptual design: select the research method(s)

Pragmatism (Saunders et al., 2007) indicate a better research philosophy for our empirical research because pragmatism considers theories, concepts, ideas, hypotheses and research finding not in an abstract form, but in terms of the roles they play as instruments of thought and action, and in terms of their practical consequences (Saunders et al., 2007). As the objective of the empirical study is to validate the relevancy of the framework in a real-life setting, pragmatism is the appropriate research philosophy for this study. Since this research starts with a framework developed from literature synthesis and a research strategy is designed to validate and refine the framework, this research uses deduction as research approach

In the empirical study, we would like to validate and refine the framework in a real-life setting and find reasoning for it.Some of the research strategy choices proposed by Saunders (Saunders et al., 2007) include experiment, survey or case study. Experimental strategy is suitable for research questions designed to test a predicted relationship between variables rather than to inquire into relationship between variables. Therefore experimental strategy is not suitable for our empirical study. A survey is usually associated with a deductive research approach, and is most frequently used to answer questions like: 'what', 'who', 'where', 'how much', and 'how many' (Saunders et al., 2007).So survey strategy is not suitable to get the required insights for our research question. Yin (Yin, 1981)defines a case study as an in-depth inquiry into a topic or phenomenon within its real-life setting. Saunders (Saunders et al., 2007) point out that a case study is the most used research method for evaluating a conceptual framework. Hence a case study, in an organization which is using software applications from different cloud platform ecosystems, is the appropriate strategy for our study. Yin (Yin, 1981)distinguishes between four case study strategies based upon two discrete dimensions – single case vs multiple cases, holistic vs embedded case. Case study of multiple organisations would have been ideal, but with the limited time available to complete this thesis, a case study of one organisation is chosen. Since the research is concerned with organization as a whole (holistic case study) instead of a number of logical sub-units (embedded case study), the case study for this thesis is a holistic single case study.

If the research is a snapshot taken at a particular time , the time horizon is cross sectional.If a series of snapshots over a given period are taken, it is longitudinal (Saunders et al., 2007). A cross sectional snapshot is chosen for this research due to time constraints.

3.2. Technical design: elaboration of the method

As the goal of the case study is to validate our framework in a real life situation, the preferred case organization is an organization which is using software applications from different cloud platform ecosystems and where the collaboration between various actors in the platform ecosystems are actively taking place. By performing the case study in such an organization, we expect to be able to interview people who are aware of the factors which enable interoperability between cloud platform ecosystems.

Our selected case should meet the following criteria.

- An organization that uses software applications from at least two different cloud platform ecosystems
- The organization is already working on projects involving cloud to cloud interoperability of platform ecosystems or willing to explore the possibilities of cloud to cloud interoperability of platform ecosystems.
- Various ecosystem actors are collaborating effectively.

A digital platform ecosystem comprises a platform owner that implements governance mechanisms to facilitate value creating mechanisms on a digital platform between the platform owner and an ecosystem of autonomous complementors and consumers(Hein et al., 2020). Platform owner is the organization representing the legal entity that owns the platform. Third-party developers or organizations that develop applications for the cloud platform are referred to as "autonomous complementors". The organization that use the applications available on the cloud platform are referred to as "consumers". Qualified persons from each ecosystem role will need to be identified to participate in our study, to ensure that various domains of enterprise interoperability are covered. These participants will also ensure that different perspectives on enabling factors for interoperability,

are received as feedback. To elaborate on various ecosystem roles in this research study, assume that the consumer organization “ABC logistics” is using the digital platform from “XYZ corp”. There is a software license agreement and a pricing model agreed between “ABC logistics” and “XYZ corp”.Based on the agreed SLAs, cloud platform of “XYZ corp” is available for “ABC logistics” to develop cloud applications. “ABC logistics” takes the service of the consultancy company “LMN consultants ” to develop cloud application in the cloud platform of “XYZ corp”. Similarly, assume that “ABC logistics” has also purchased cloud platform from “DEF corp” and takes the service of the consultancy company “PQR consultants ” to develop cloud application in the cloud platform of “DEF corp”. In this scenario “ABC logistics” is the consumer organization, “LMN consultants ” and “PQR consultants” are Autonomous complementors - “LMN consultants ” are specialized in cloud platform of “XYZ corp” and “PQR consultants ” are specialized in cloud platform of “DEF corp”.

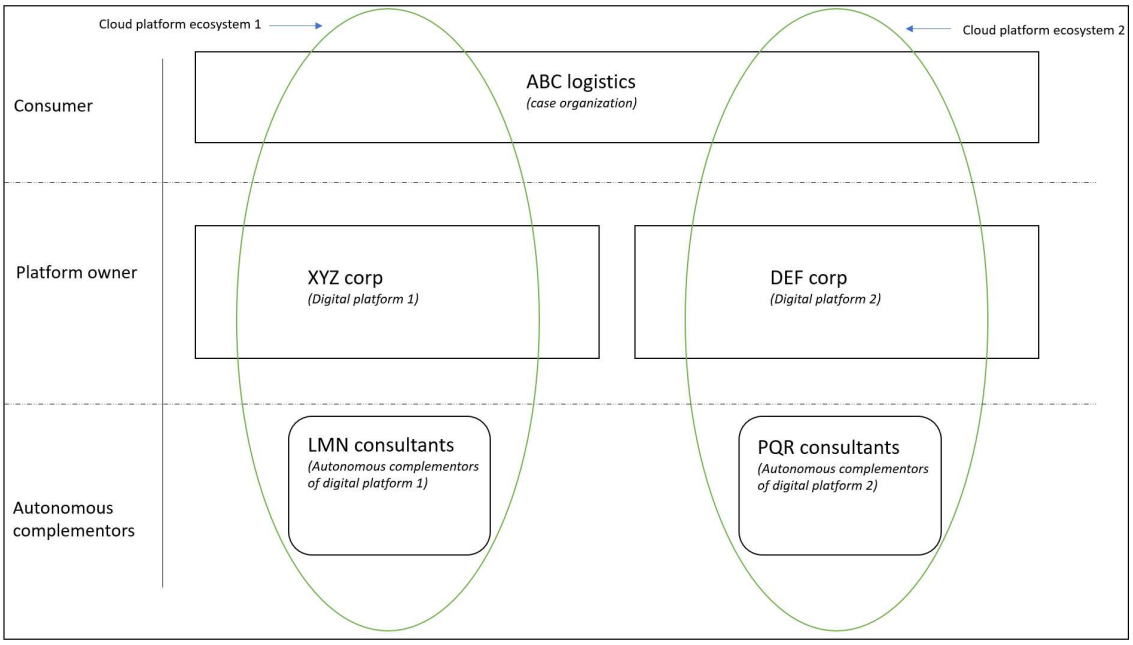

Fig 4: Relationships in the ecosystems in case organization

To select eligible individuals to participate in interviews, the following criteria are defined :

- The respondent has an academic education, for providing in-depth reasoning in argumentation.
- The respondent has a level of knowledge or experience with cloud platforms.
- The respondent is familiar with the subject of cloud platform interoperability.
- The respondent is involved either directly or indirectly in any cloud-to-cloud interoperability project(s)

Ecosystem role	Organization details	Role of participants in their organization
Consumer	Case organization	Enterprise Architect
Consumer	Case organization	Group Leader - Digital Platforms
Consumer	Case organization	Business Analyst - ERP subject matter expert
Consumer	Case organization	Integration specialist
Consumer	Case organization	Chief Information Security Officer

Autonomous complementors - Cloud Platform Ecosystem 1	Implementation partner / System integrator (Third party organization)	Principal consultant
Autonomous complementors - Cloud Platform Ecosystem 1	Implementation partner / System integrator (Third party organization)	Application developer
Autonomous complementors - Cloud Platform Ecosystem 2	Implementation partner / System integrator (Third party organization)	Senior consultant / Team lead
Autonomous complementors - Cloud Platform Ecosystem 2	Implementation partner / System integrator (Third party organization)	Application developer

Table 4: List of individuals to participate in interviews

Table 4 provides a list individuals selected to participate in interviews. Cloud platform itself is delivered "as a service" by the platform owner organization to consumer organization. Platform owner organization is only making the cloud platform available and not involved itself in the development of cloud applications. So the ecosystem role "platform owner" is out of scope of this research. The expectation is that "Autonomous complementors" from System integrator organization are highly knowledgeable about the respective cloud platforms where they are developing the applications.

Secondary data are data that you analyse which were originally collected for some other purpose (Saunders et al., 2007).Access to secondary data are unlikely options for data collection due to the security policies of the case organization. Collecting primary data will be the choice for this thesis. Collection of primary data through observation will not be possible due to the duration of the research. Collecting primary data through interviews will be the choice for this thesis. Interviews are categorised as structured, semi-structured or unstructured.. Semi-structured interview where the questions based on theoretical framework developed in section 2, is preferred for this empirical study. In this method, the questions can be prepared in advance and used as a guidance while conducting the interview.

We will collect the data for our study by conducting a semi-structured interview. A semi-structured interview allows the researcher to have a list of themes and key questions, with the option to add, re-sequence or omit themes or questions to explore the research question(s) or prompt further discussion (Saunders et al., 2007).

Interview protocol

To ensure that the interview questions align with our empirical study and to organize an inquiry-based conversation, an interview protocol is defined. The interview protocol consists of 3 sections. The aim of the primary section is to get an understanding of the familiarity of the interviewees with the subject without discussing any of the listed themes for the interview. The purpose of the questions in the first section is to openly discuss various factors enabling the interoperability of cloud platform ecosystem in enterprises, before participants see the framework and be biased by it.

The second part of the interview will be used to validate the framework, by checking with respondents if the enabling factors mentioned in the framework are relevant. As besides validity, we also would like to get an in-depth understanding of the reasons behind the relevancy of each enabling factors, the respondents will also be asked for the reasoning behind their answer by asking *why* questions. At the end of the second section, we would also ask respondents to rank the enabling factors, according to the relevance and importance of these factors, based on their work experience.

In the closing part of the interview, the main aim is to get an understanding of the overall impression of our framework and to give an opportunity to point out missing elements in the framework and

elements within. All interviews will be recorded to prevent excessive note taking. Permission will be asked on forehand and background information will be sent in advance. By sending background information in advance and asking permission, we offer the interviewees the opportunity to be able to prepare for the topic. This process improves the validity and reliability of the interview. The recordings will be deleted after they have been processed.

Before commencing the actual interviews, pilot interview will be conducted with one or two key informants to determine if our questions are clear and identify any limitations within the interview design. Appendix G contains the complete list of questions.

3.3. Data analysis

Qualitative data is non-numeric data or non-quantified data and is characterised by its richness and fullness. This type of data will need to be condensed, coded and categorised to group them according to themes to make sense of these data (Saunders et al., 2007).Data collection, analysis and interpretation are an interrelated and interactive set of processes in qualitative research. Analysis often occurs during the collection of data as well as after it. Saunders (Saunders et al., 2007) highlights that interview should be audio-recorded and subsequently transcribed, in qualitative research interviews. Therefore all interviews will be transcribed and analysed as part of this empirical study. A transcription summary will be created to summarize the main points of the transcript of the interviews.

Thematic analysis offers a systematic yet flexible and accessible approach to analyse qualitative data(Braun & Clarke, 2006).It involves a researcher coding her or his qualitative data to identify themes or patterns for further analysis. On the other hand, Deductive Explanation Building involves an incremental attempt to build an explanation by testing and refining a predetermined theoretical proposition. Deductive Explanation Building is linked to the need to specify theoretical propositions before the commencement of data collection and analysis. Since a theoretical framework is already created as part of this thesis (section 2), we would use Deductive Explanation Building method instead of Thematic analysis for qualitative data analysis.

As our research objective is to validate and refine the conceptual framework about enabling factors for interoperability of cloud platform ecosystems, priori codes will be created based on “enabling factors” mentioned in the theoretical framework. Since the semi-structured interview protocol will be based on theoretical framework developed in section 2, our expectation is that it should be possible to map the answers from respondents to these defined priori codes .The way in which respondents give answers can vary. In order to decide whether an “enabling factor” should be included in the theoretical framework or not, we will ask respondents for reasoning for their answers and ask follow-up questions. Based on the responses we get and the analysis of the responses, we will decide whether to keep the element in the framework or not. Table 5 contains the coding table to map the response from the respondents for each question.

Framework validation	**Code**	**Meaning**
VALIDATED	Strongly agree	Respondent agrees with "enabling factor" and can substantiate it based on his/her experience
	Agree	Respondent agrees with "enabling factor" and can provide reasoning

NON-VALIDATED	Neither agree nor disagree	Respondent has no opinion about the "enabling factor" or is unable to provide a proper justification for the choice.
	Disagree	Respondent disagrees with "enabling factor" and can provide reasoning
	Strongly disagree	Respondent disagrees with "enabling factor" and can substantiate it based on his/her experience

Table 5: Coding of responses of participants

These responses will be further aggregated to determine whether an element is validated or not. When the code is “Strongly Agree” or “Agree”, they will be aggregated to “Validated” (Positive response). When the code is “Neither Agree nor Disagree”, “Disagree” or “Strongly Disagree”, they will be aggregated to “Non-Validated” (Negative response). When the number of “Validated” response is greater than that of “Non-Validated” response, the element in the framework is considered as “Validated”. This is to make sure that the element is a “common“ interoperability factor validated by larger cross section of respondents. If it is only validated by a few respondents, it could mean that the element is an enabling factor only for a limited scenario or under special situations.

Respondents are also asked to rank the enabling factors according to their relevance and importance. Responses from all the participants will be aggregated to produce an overall ranking of the “enabling factors” for the interoperability of cloud platform ecosystems.

The initial theoretical proposition may be revised after the conduct of research, by altering the “enabling factors” in the framework based on feedback, as part of this Deductive Explanation Building qualitative data analysis technique. New themes may need to be added to the framework as part of the research. This will allow for follow-up research, in the form of a second design-evaluation loop according to the Design Science research methodology. However this will not be conducted due to the limited timeframe of this research.

3.4. Reflection w.r.t. validity, reliability and ethical aspects

Construct validity

According to Saunders et al. (2019), construct validity is defined as the extent to which the measurement tools actually measure what is intended. We will follow well-defined procedure to gather data, through semi-structured interviews with questions constructed based upon literature found definitions, to ensure the construct validity. In order to validate the answers given, we will apply triangulation wherever possible. Saunders (Saunders et al., 2007) describe triangulation as using more than one source of data and method of collection to confirm the validity of research data.In an attempt to improve the construct validity, we will ask key informants for a feedback on the draft version of the report.

Internal validity

Saunders (Saunders et al., 2007) state that internal validity, or measurement validity is the extent to which a scale or measuring instrument measures what it is intended to measure. The respondents will be selected based on specific criteria. They are experts and their responses are of value to the research. Interviewing people from different background on the same conceptual framework will increase internal validity. The objective is that the interview results lead to an improvement of the

model. During the interviews the researcher will look for mutual clarification of questions and responses as much as possible (Saunders et al., 2007) to improve internal validity.

External validity
The external validity defines the generalizability of the results to all relevant contexts (Saunders et al., 2007). This research only uses a single case study and this could pose a threat to the external validity of the research results, due to the possible lack of generalization to other research settings. An attempt to minimize this threat is made in the participant selection by using experienced respondents from case organization and partner organizations.The respondents will be selected based on specific criteria to ensure broad and varied expertise.

Reliability
Reliability is defined as the extent to which the data collection technique or techniques will yield consistent findings, similar observations would be made, or conclusions reached by other researchers or there is transparency in how sense was made from the raw data (Saunders et al., 2007). This research follows the Design-science research paradigm and all the steps are described in detail. Therefore this research can be reproduced by any researcher.

Ethical aspects
The research and interviews will be completed in an ethically responsible manner following the below guidelines put forth by Saunders (Saunders et al., 2007) :

- Integrity and objectivity of the researcher
- Respect for others
- Avoidance of harm
- Privacy of those taking part
- Voluntary nature of participation and right to withdraw
- Informed consent of those taking part
- Ensuring confidentiality of data and maintenance of anonymity of those taking part
- Responsibility in the analysis of data and reporting of findings
- Compliance in the management of data
- Ensuring the safety of the researcher

4. Results

In this chapter, we briefly describe the conduct of the study. We indicate what our research population consisted of, and the answers which were given for each enabling factor. We will also share the findings of the data analysis of transcribed interviews and finally the modified practical framework.

4.1. Case description

Our selected case was an organization in manufacturing sector in the Netherlands which met the requirements as stated in the methodology section. The case organization uses software applications from two different cloud platform ecosystems. The first digital platform is built upon prebuilt content for integration and analytics. The case organization contracted a consulting firm to build applications for them in this digital platform. Case organization (consumer), Digital platform owner (corporation owning the digital platform) and Autonomous complementors (consulting firm) formed the first cloud platform ecosystem. The second digital platform applies machine learning and advanced analytics for real-time monitoring of vast quantities of industrial data from SCADA systems. The case organization has contracted a consulting firm to implement this cloud digital platform and develop cloud

applications in this platform. These cloud actors formed the second cloud platform ecosystem in the case organization.

Overview of respondents that have been interviewed, together with the role in their own organization as well as the role that their organization has within the ecosystem is mentioned in table 6. The complete overview of the respondents and their answers to main enabling factor is mentioned in Appendix I

Role of the company respondent represents in Platform Ecosystem	Function	Education	Years of experience in company	Years of experience in this field	Interview Number
Consumer	Enterprise Architect	University	4	14	int_C1
Consumer	Integration specialist	University	6	15	int_C2
Autonomous complementors - Cloud Platform Ecosystem 2	Senior consultant / Team lead	University	1	8	int_AC2 - 1
Autonomous complementors - Cloud Platform Ecosystem 2	Application developer	Bachelors	2	2	int_AC2 - 2
Autonomous complementors - Cloud Platform Ecosystem 1	Application developer	Bachelors (technical)	4	4	int_AC1 - 2
Consumer	Chief Information Security Officer	University	2	16	int_C3
Autonomous complementors - Cloud Platform Ecosystem 1	Director – Business Consulting	Business economist(Diploma)	6	22	int_AC1 - 1
Consumer	Group Leader – Digital Platforms	HBO (Technische Informatica)	6	16	int_C4

Table 6: List of participants

4.2. Feedback from the pilot interview

We have received the feedback for the pilot interviews from two respondents to whom we presented the interview protocol. It was discovered in the pilot phase that it is beneficial to share some information about the topic beforehand to provide an orientation to the respondents about the interview. Therefore, a brief background information about the interview topic was sent to the respondents through email, before conducting the actual interview. First part of the interview protocol, which contained the questions to get an understanding of the familiarity of the interviewees with the subject, was also sent as part of this information sharing email to the respondents, in order to manage the time and for the respondents to better align with the interview. There was also a question regarding the rating of the "enabling factors" based on their significance. In the pilot interviews it became clear that rating of the "enabling factors" during the interview was cumbersome. It was decided to request the respondents to send the top 5 or top 10 "enabling factors" via email

after the interview. Eventually only two respondents responded with the list of top 5 "enabling factors". However, the email did not explain the basis for the rating. Therefore, a different approach was followed to rank the "enabling factors". This is mentioned under the "Data Analysis" section. It was noted during the pilot interview that providing a brief description of the "enabling factors" significantly improved the interview process. A brief description of each enabling factor was shown to the respondents during the interview.

4.3. Data Analysis

In the introduction part of the interviews, we asked the respondents regarding the main enabling factors for interoperability according to them. This question was part of the information sharing email and it allowed the respondents to prepare for this question. The results are summarized in following table 7 :

Interview code	Main enabling factors for interoperability according to respondent.
int_C1	Main enabling factor for interoperable solutions (cloud or non cloud), is to follow open standards in design and development of applications
int_C2	Main enabling factor is communication between application components using APIs and metadata. From business perspective, the main enabling factor is business flexibility.
int_AC2 - 1	Main enabling factor is the business demands . For example, modular based IT architectures which provides agility to business need interoperable cloud applications.
int_AC2 - 2	Main enabling factor is digital transformation of organization. Moving towards cloud native applications and use of multi-cloud services.
int_AC1 - 2	Main enabling factor is business requirements for additional functionalities. From a technical perspective cloud interoperability is facilitated by having interface standards between various PaaS providers
int_C3	Cloud interoperability can leverage services from various cloud vendors. This is very important for organization to maintain its competitive edge.
int_AC1 - 1	Organizations need to avoid information silos and fragmented processes while moving into the cloud. This is the main enabler for cloud interoperability. Some organizations follow cloud first strategy. Cloud interoperability is essential for these organizations to have a single source of truth, accurate data.
int_C4	Main enabling factor is cost-benefit analysis to migrate on-premises datacenters to cloud. Another enabling factor is innovation – for example cloud analytical applications, customer collaboration in cloud etc

Table 7: Main enabling factors for interoperability according to respondents, (in the introduction part of the interview).

The responses like "**open standards**" (interview code int_C1) , "**APIs and metadata**"(interview code int_C2) and "**business demands**"(interview code int_AC2 – 1) could be mapped to the enabling factors which were already available in the framework. We found that other responses such as "**agility to business**" (interview code int_AC2 – 1), "**digital transformation**" (interview code int_AC2 – 2), "**competitive edge**"(interview code int_C3), "**cost-benefit analysis**"(interview code int_C4) and "**innovation**" (interview code int_C4) as possible enabling factors, which are not available in the framework. These enabling factors should be researched further in a future study to check its validity.

For the confirmatory part of the interviews, the responses from the 8 interviews were transcribed and were analysed. Coding of responses of participants were performed based on the coding framework mentioned in table 5 (section 3.3). All responses provided by respondents were transformed to one of the values in table 5, for analysis purposes.

The results from the confirmatory part of the interviews are summarized in appendix K.

The following section elaborates on our findings regarding the responses for confirmatory part of the interviews.

The interoperability of business

Results on interoperability of business is discussed below, under respective interoperability dimensions. Results for Technological dimension and Organizational dimension are moved to appendix L due to page limitation. Only the results for Conceptual dimension is mentioned below.

Conceptual dimension

All respondents positively validated the enabling factor **vendor lock-in avoidance**. Some of the respondents commented that it is possible to avoid vendor lock-in in the IaaS and PaaS layer, whereas it is difficult to avoid it in the SaaS layer. One of the feedbacks from the respondents was "*The more sophisticated and specialised tool you need, you have less options to avoid lock-in*" (interview code int_C1). Another feedback was that *"A multi-cloud strategy where an organization uses two or more cloud services from different vendors supporting interoperability can avoid vendor lock-in"*(interview code int_C4) and thus substantiating that avoidance of vendor lock-in is an enabling factor for interoperability of cloud platform ecosystems. Enabling factor **Scalability** is validated as one of the main enabling factors for interoperability by most of the respondents. This enabling factor was validated by justifying that "*When the application is interoperable, resources can be added on the infrastructure layer on the fly and scale as rapidly as the customers require*" (interview code int_C2) which corroborated the fact that "Scalability" is one of the important enabling factors for the interoperability of cloud platform ecosystems.Concerning the enabling factor **regulations**, most respondents agreed that regulations are important but did not validate it as an enabling factor for interoperability. Two of respondents who were positive about this enabling factor have given the arguments that "*Regulations can enforce providers to adhere to standards that promote interoperability*" and "*Regulations can indeed prevent monopoly of big cloud players.*" (interview code int_AC1 – 1). However, since only two out of eight respondents considered "regulations" as an enabling factor, this element cannot be considered as a relevant enabling factor. Enabling factor "**Inter-organizational supply chain in networked enterprises**" is also validated as part of the interview. As a part of validating this enabling factor, one of the respondents has mentioned that "*Interoperable cloud applications can avoid information silos and provide the user with single source of truth*" (interview code int_AC1 – 1). Other responses which supported this enabling factor are "*Interoperable cloud allows suppliers and buyers to connect and do business on a single platform*" and "*Supports customer collaboration with B2B cloud network*" (interview code int_C2). Five respondents have positively validated this enabling factor and hence this element will be retained in the final practical framework.

The interoperability of processes

Results on interoperability of process is discussed below, under respective interoperability dimensions. Results for Technological dimension and Organizational dimension are moved to appendix L due to page limitation. Only the results for Conceptual dimension is mentioned below.

Conceptual dimension

Enabling factors "**Alignment of cross organizational business process**" and "**Supporting distributed business process**" were mentioned as part of interoperability of process on a conceptual layer. "Alignment of cross organizational business process" were validated by two respondents who mentioned "*Business process modelling and interoperable cloud solutions should go hand in hand.*" (interview code int_C2) and "*Once the business processes are streamlined, it can be checked what all activities can be outsourced to cloud."* (interview code int_C3). Two respondents counter argued that "*There is no strict need to have specifically designed business process to have cloud solutions. It is other way around. Cloud can support business process. Cloud can provide flexibility in business process. It can help in organic growth rather than in a revolution*" (interview code int_C1) and "*It is not a prerequisite that business process needs to be harmonized before the organization moves to cloud*" (interview code int_AC1 – 1). When considering the arguments from positive response and negative response for the element "Alignment of cross organizational business process", it is clear that this element cannot be considered as a general enabling factor. It could be that this element is supporting interoperability in specific situations but not in general. Therefore, this element is not considered in the final practical framework. "Supporting distributed business process" was validated by seven respondents as an enabling factor for cloud interoperability. One of the examples given by one of the respondents supporting this element was that "*machine learning, OCR etc needs additional computing capacity and can be outsourced to cloud solutions*" (interview code int_AC2 – 1). Another supporting statement was that "*Business process can be outsourced as a service to cloud providers*" (interview code int_AC2 – 2). It is clear from the responses that "Supporting distributed business process" is an enabling factor for cloud interoperability.

The interoperability of services

Results on interoperability of services is discussed below, under respective interoperability dimensions. Results for Technological dimension and Organizational dimension are moved to appendix L due to page limitation. Only the results for Conceptual dimension is mentioned below.

Conceptual dimension

Enabling factor "**Service oriented architecture**" (SoA) is validated by most of the respondents as an enabling factor for interoperability of services. The feedback from the interviews were that Service oriented architecture enables interoperability of cloud services because "*With SoA, the programming languages used by the service is decoupled from the cloud environment, making it easier to interoperate*" and "*principles used in SOA is used for creating multi-cloud applications*" (interview code int_AC1 – 2). With SoA, "*Only high-level request needs to be designed. You can have API calls to implement the design*" (interview code int_AC2 – 1). Based on the feedback from the interviews, SoA is validated as an enabling factor because "*SoA is composed of loosely coupled services. Interoperable cloud applications are loosely coupled via APIs*" (interview code int_AC1 – 1). One respondent has mentioned that SoA is "*General enterprise architect principle. Cloud is just an extension*" (interview code int_C2). About the enabling factor " **Model-driven approach**" , one of the respondents has explained that using model driven approach "*An abstraction of a model can be defined without reference to the technologies that may be used to implement it*" (interview code int_AC2 – 1) and this can support in interoperability. It was also mentioned in one of the interviews that Model-driven approach "*provides a separation of code between views that display, the data store and pure logic part. This helps in improving interoperability and less adjustments are needed*" (interview code

int_AC2 – 2). Only four out of the eight respondents have positively validated this enabling factor. It could be that because of the technical nature of this enabling factor, only those respondents with technical background have positively validated it, while others have ignored this element. As per the validation rule, only when the number of positive validations is more than that of negative validations, the element is considered for final practical framework. Therefore, this element is not considered for the final framework. Regarding the enabling factor "**Cloud standardization projects**", only one respondent has positively validated it stating that "*Standards and Industry best practices promote interoperability*" (interview code int_C3). This enabling factor is therefore not included in the final practical framework. The reason why it was not validated by other respondents could be due to the lack of information in industry about Cloud standardization projects.

The interoperability of data

Results on interoperability of data is discussed below, under respective interoperability dimensions. Results for Technological dimension and Organizational dimension are moved to appendix L due to page limitation. Only the results for Conceptual dimension is mentioned below.

Conceptual dimension

"**Trust model in cross-clouds applications**" was unanimously validated by all the respondents. It was mentioned in one interview that "*If you cannot trust other party, you cannot have interoperable solution*" (interview code int_C1) which makes trust model one of the most important enabling factors.Trust model makes it "*easier to implement secure communication between multiple cloud tenants*" (interview code int_AC2 – 1) and is "*quite beneficial from security perspective of multi cloud application*" (interview code int_AC2 – 2).Therefore this element is available in the final practical framework.Regarding the "**Information interoperability**", three respondents have positively validated it and four respondents have provided negative response. The main reason why there is a split between the respondents seems to be due to the wide nature of this enabling factor. Those who have supported this enabling factor have mentioned that there should be "*some standard mechanism for interoperability. Mapping tables can be used for this*" (interview code int_C2) and "*it is required for single source of truth for data from multiple services"* (interview code int_AC1 – 1). However, those who gave negative response mentioned that "*it is up to business to make sense of data*" (interview code int_AC2 – 1). It was also mentioned that "*Information interoperability is on a logical layer and it is independent of whether it is cloud platform or not*" (interview code int_AC2 – 2) and hence "*it is not necessary for information to be interoperable for cloud interoperability.*" (interview code int_C3). This element is not included in the practical framework. Concerning "**Data Portability**", the main response was that it is not important for interoperability and that there are "*intermediary which can do the translation for you*" (interview code int_C1). Hence the enabling factor "Data Portability" is not included in the final practical framework. The enabling factor "**Platform-independent database abstraction layer**" was also not validated but one respondent has mentioned that this enabling factor can "*help to avoid database vendor lock-in*" (interview code int_C2) and it helps in "*migrating applications from one DB to another DB*" (interview code int_C3). Since only two out of eight respondents provided positive feedback, this element is not included in the final practical framework.

General findings and closing part of the interviews

At the end of the interview, each respondent was asked whether they would like to mention anything additional about the framework and if any element was missed. This has revealed a lot of interesting aspects which could be potentially added to framework such as "**cloud licensing model**"(interview code int_C1), "**change management of cloud applications**" (interview code int_AC2 – 1) and "**governance of interoperable clouds**" (interview code int_C3). One respondent has mentioned that

framework did not include organizational aspects like setting up of "**cloud center of excellence**". All these findings should have been further researched and validated but were not chosen for this research due to time constraints. Asked about overall impression of the framework, one of the respondents mentioned that "*the framework looks good"* (interview code int_AC2 – 1). There was no other specific remark against the overall impression of framework. The respondents were also asked to what extend they consider the framework to be useful for implementing interoperable cloud platform ecosystems. Two of the respondents mentioned that framework "*covered a lot of areas of enterprise interoperability"* (interview code int_C1) and that *"it can be used as a checklist by organization considering cloud interoperability projects, to co-ordinate discussion among various stakeholders"*(interview code int_AC1 – 1). One of the respondents has mentioned that there is "*no need for a specific framework for cloud applications. The existing ITSM framework can be used after modifying with additional cloud specific elements*." (interview code int_AC1 – 1). However, this comment appeared to be based on the fact that the respondent is only taking into consideration the Information Technology services part of cloud interoperability.

Ranking of enabling factors

For ranking the enabling factors, all the "validated" enabling factors were selected and were sorted in a descending order based on the number of respondents who validated the particular element. This list is further sorted on the number of "Strongly Agree" response to finally rank the enabling factors. The summary of ranking is provided in table 8.

SA	Strongly agree
A	Agree
NADA	Neither agree nor disagree
D	Disagree
SD	Strongly disagree

Enabling factors	Consumer				Autonomous		Autonomous		Validation		Aggregate				
	C1	C2	C3	C4	AC1 - 1	AC1 - 2	AC2 -1	AC2 - 2	Validated	Non-Validated	SA	A	NADA	D	SD
Security	SA	A	SA	SA	SA	A	SA	A	8	0	5	3	0	0	0
Scalability	SA	A	SA	SA	SA	A	SA	A	8	0	4	4	0	0	0
Trust model in cross-clouds applications	SA	A	SA	SA	SA	A	A	A	8	0	4	4	0	0	0
Service Level agreement	SA	A	A	SA	SA	A	SA	A	8	0	4	4	0	0	0
Vendor lock-in avoidance	A	A	SA	A	SA	A	SA	A	8	0	3	5	0	0	0
Supporting distributed business process	D	A	A	A	A	A	SA	SA	7	1	2	5	0	1	0
Standardized APIs and data models	NADA	SA	A	A	A	A	SA	A	7	1	2	5	1	0	0
Service oriented architecture	A	SA	NADA	A	A	A	A	A	7	1	1	6	1	0	0
Middleware	SA	A	A	A	A	NADA	A	A	7	1	1	6	1	0	0
Open libraries	A	A	A	A	NADA	A	SA	NADA	6	2	1	5	2	0	0
Cloud modelling framework and cloud modelling languages	NADA	SA	A	NADA	NADA	SA	SA	A	5	3	3	2	3	0	0
Inter-organizational supply chain in networked enterprises	D	A	NADA	A	A	NADA	SA	SA	5	3	2	3	2	1	0
Microservices	A	NADA	NADA	A	A	A	NADA	SA	5	3	1	4	3	0	0
Data liberation	A	A	A	NADA	NADA	A	A	NADA	5	3	0	5	3	0	0

Table 8: Ranking of enabling factors

Based on the above mentioned process for ranking the enabling factors, top 5 enabling factors are "**Security**", "**Scalability**", "**Trust model in cross-clouds applications**", "**Service Level agreement**" and "**Vendor lock-in avoidance**". Incidentally all these five enabling factors are validated by all eight respondents.

4.4. Validated Framework

Based on the results of the case study we finalized the proposed framework. All the validated enabling factors are highlighted in green colour in the table 9. New elements which are proposed by respondents but were not originally available in the initial theoretical framework are mentioned in yellow colour. The non-validated elements were removed from the framework.

Interoperability dimensions	Interoperability levels	Enabling factors	Comments
Conceptual	Business	Vendor lock-in avoidance	This element is validated and will remain in final practical framework
		Scalability	This element is validated and will remain in final practical framework
		Inter-organizational supply chain in networked enterprises	This element is validated and will remain in final practical framework
	Process	Supporting distributed business process	This element is validated and will remain in final practical framework
	Service	Service oriented architecture	This element is validated and will remain in final practical framework
	Data	Trust model in cross-clouds applications	This element is validated and will remain in final practical framework
Technological	Process	Cloud modelling framework and cloud modelling languages	This element is validated and will remain in final practical framework
		Microservices	This element is validated and will remain in final practical framework
	Service	Middleware	This element is validated and will remain in final practical framework
		Open libraries	This element is validated and will remain in final practical framework
	Data	Standardized APIs and data models	This element is validated and will remain in final practical framework
		Security	This element is validated and will remain in final practical framework
Organizational	Service	Service Level agreement	This element is validated and will remain in final practical framework
	Data	Data liberation	This element is validated and will remain in final practical framework
Additional findings	New element	Cloud licensing model	Input received as part of interview (int_C1).This element requires a follow-up research and needs to be added to the framework in the form of a second design-evaluation loop according to the Design Science research methodology.
	New element	Change management of cloud applications	Input received as part of interview (int_AC2– 1).This element requires a follow-up research and needs to be added to the framework in the form of a second design-

			evaluation loop according to the Design Science research methodology.
	New element	Governance of interoperable clouds	Input received as part of interview (int_C3)This element requires a follow-up research and needs to be added to the framework in the form of a second design-evaluation loop according to the Design Science research methodology.
	New element	Agility to business	Input received as part of interview (int_AC2 – 1)This element requires a follow-up research and needs to be added to the framework in the form of a second design-evaluation loop according to the Design Science research methodology
	New element	Digital transformation	Input received as part of interview (int_AC2 – 2)This element requires a follow-up research and needs to be added to the framework in the form of a second design-evaluation loop according to the Design Science research methodology
	New element	Competitive edge for business	Input received as part of interview (int_C3)This element requires a follow-up research and needs to be added to the framework in the form of a second design-evaluation loop according to the Design Science research methodology
	New element	Cost-benefit analysis	Input received as part of interview (int_C4)This element requires a follow-up research and needs to be added to the framework in the form of a second design-evaluation loop according to the Design Science research methodology
	New element	Innovation	Input received as part of interview (int_C4)This element requires a follow-up research and needs to be added to the framework in the form of a second design-evaluation loop according to the Design Science research methodology

Table 9: final framework of enabling factors

5. Discussion, conclusions and recommendations

In this chapter we will reflect on the various stages of research process and discuss limitation and deviation from the plan. We will scrutinize the empirical findings to extract insights from the study. We will also analyse and reflect on the validity and reliability of our research and provide a conclusion and recommendations at the end.

5.1. Discussion – reflection

In this chapter we will reflect on the various stages of research process

5.1.1. Reflection on literature research

Once we have selected the scientific literature for our research based on search query, it needed to be evaluated to extract useful information. INTEROP NoE framework was used as a basis for performing data extraction. Based on this template, the coding for enabling factors was performed. Use of INTEROP NoE framework for data extraction was very handy in extracting the information and categorizing the enabling factors to different interoperability domains. During the semi-structured interviews, this categorization under various interoperability domains proved to be convenient to focus the questions to the respondents. Probably the only weakness of this approach was that the use of INTEROP NoE framework resulted in a framework with large number of elements, as it limited the ability to provide a higher order code because elements were placed under various dimensions and domains.

5.1.2. Reflection on case study

This section describes the limitations of case organization based on the requirements mentioned in the methodology section (Section 3). The selected case organisation fulfilled all the selected requirements except the requirement that the case organization should be working on projects involving cloud to cloud interoperability of platform ecosystems. The implementation of second cloud platform ecosystem in the organization is still ongoing and hence there were no interoperability scenarios between the two cloud platform ecosystems available yet in the organization. However, the organization makes use of multiple cloud applications already and had moved some of the on-premise applications to cloud data center. So, the knowledge of cloud interoperability existed within the employees of case organization. The employees from consulting firms (Autonomous complementors) were already experienced with cloud platform interoperability from other customers.

5.1.3. Deviations from Planned Steps

The deviations from the planned steps in the interview protocol and other limitations are outlined in this section.

The case organization has factories in both Ukraine and Russia. Due to the ongoing conflict in Ukraine, the production in Ukraine was stopped and some of the production was transferred to other locations. The case organization has also suspended all the activities in Russia until further notice. The Group Crisis Team which was formed to support employees and ensure business continuity during this crisis, has affected the availability of some of the respondents. Also, a joint venture deal of the case organization, which was kept confidential until the announcement, has caused additional workload for some of the respondents, which affected their availability.

The interviews of the consultants from consulting firms were done via MS-Teams since the consultants were not onsite. As a result, the facial expressions and non-verbal behavior were less recognizable in the interview. All the interviews of the employees in the case organization were face to face interviews where the voice recording was done. All the interviews were subsequently transcribed.

For the interviews, we initially planned for 9 different respondents and all of them verbally agreed to participate in the interview. However due to some unforeseen circumstance, one of the planned respondents had to travel to Canada and was unavailable for the interview. It would have been beneficial for the empirical study to get the perspective of this respondent since this respondent is a business analyst with strong ERP expertise, which might have given additional perspectives regarding enterprise interoperability with respect to ERP.

5.1.4. Interpretation of the results

In this section we discuss the results of our case study and compare them with the literature to check if they are consistent with each other. Possible reason for differences in the results are also provided in this section.

The interoperability of business

Results on interoperability of business is discussed below, under respective interoperability dimensions.

Conceptual dimension

From the literature review, "**Avoidance of vendor lock-in**" is mentioned as one of the main enabling factors from a business perspective to support cloud interoperability(Kaur et al., 2017; Toosi et al., 2014; Ünver, 2019). This was positively validated by all the eight respondents. Toosi (Toosi et al., 2014) mentioned "**Scalability**" as an enabler for cloud interoperability by supporting the growth in the scale of existing applications or surge in demand for a service. "Scalability" was positively validated by all eight respondents. As per the literature review, enforcing competition law also acts as an enabler for interoperability from business perspective.(Ünver, 2019).However in the empirical study it was found that most of the respondents did not identify "**regulations**" as an enabler. This could be explained by the fact that "regulations" is a niche area and the respondents lacked experience in this area. "**Inter-organizational supply chain in networked enterprises**" is mentioned in the framework as an enabling factor because seamless integration of entities within (intra) and outside (inter) the enterprises (e.g. suppliers, business partners, employees, workers, customers) increased efficiency in intra- and interorganizational value/supply chains(Mezgár & Rauschecker, 2014). This element was validated by the respondents and provided use cases such as "*cloud allows suppliers and buyers to connect and do business on a single platform*" (interview code int_C2).

Technological dimension

Regarding the enabling factors "**Market Platform**" mentioned under the technology dimension, it was validated by only three respondents. It was clear from the literature that main objective of the market platform is to bring customers and service providers together(Oberle & Fisher, 2010). The enabling factor "**Aggregator**" aggregates many small and modular services into value-added, complex solutions for certain needs.(Oberle & Fisher, 2010). This element was not validated by any respondent. One possible reason why these elements were not validated in the empirical study could be because these enabling factors are not yet popular in the industry and certainly not used in the case organization. Additional research is required to clarify the validity of these elements.

Organizational dimension

The enabling factor "**Provider-centric interoperability and client-centric interoperability**" mentioned under the organization dimension were positively validated only by three respondents. All the respondents were familiar with Provider-centric approach and client-centric approach, but majority of the respondents believed that these approaches are not impacting the cloud interoperability. As per the framework validation rule mentioned in section 3.3, this element was not included in the final practical framework. Additional research is required to clarify this inconclusive result.

The interoperability of processes

Results on interoperability of process is discussed below, under respective interoperability dimensions.

Conceptual dimension

From the literature review, it was found that **alignment of cross organizational business process**(Mezgár & Rauschecker, 2014) is a factor in enabling cloud interoperability. During the empirical study, this element was not validated and one of the main feedback from the respondents is that "*It is not a prerequisite that business process needs to be harmonized before the organization moves to cloud*" (interview code int_AC1 – 1).The reason for discrepancy in the results of literature review and empirical study can be justified by the fact that this element is supporting interoperability in specific situations but not in general as a whole and it should be taken case by case for each individual organisation. The enabling factor "**Distributed business processes and business-to-business integration**"(Mezgár & Rauschecker, 2014) is validated by seven respondents and is included in the final practical framework.

Technological dimension

On the technological layer, enabling factors from literature research "**Cloud modelling framework and cloud modelling languages**"(Bouzerzour et al., 2020) and "**Microservices**"(Bouzerzour et al., 2020) were validated by respondents as enabling factors and are included in the final practical framework. Since these elements are more technical in nature, the supportive comments from developers such as "*Cloud modelling framework and cloud modelling languages reduce cloud development time and time to market*" (interview code int_C2) and "*microservices are composed of many loosely coupled and independently deployable smaller components which supports interoperability*" (interview code int_AC1–2) confirmed the importance of these elements.

Organizational dimension

During the literature research, "**Cloud Computing Standardization Organizations**" was added in the theoretical framework because it brings organizations together to cooperate towards the purpose of wider adoption of standards during development of cloud computing technologies(Kaur et al., 2017; Toosi et al., 2014).Summary of the feedback from the interviews is that big companies may not like restrictions imposed by standards organization but following standards could make cloud technology compatible with each other.It became clear during the empirical study that Cloud Computing Standardization Organizations are not yet popular in the industry because majority of the respondents did not validate this element. This element is not included in the final practical framework.

The interoperability of services

Results on interoperability of services is discussed below, under respective interoperability dimensions.

Conceptual dimension

During the empirical study, only the enabling factor "**Service oriented architecture**"(Bouzerzour et al., 2020) was positively validated by the respondents and the enabling factors "**Model-driven approach**" (Bouzerzour et al., 2020) and "**Cloud standardization projects**"(Kaur et al., 2017) were not validated. Due to the deep technical nature of the enabling factor "Model-driven approach" , only respondents with technical background has positively validated it. Further research involving multiple case studies is recommended to validate this element. As majority of the respondents did not provide a valid feedback regarding the enabling factor "Cloud standardization projects", it appears that there is a lack of knowledge among the respondents regarding the cloud standardization project or there is limited

evidence in industry about cloud standardization projects. Further research is needed to conclude the importance of this element.

Technological dimension

Enabling factor "**Open libraries**"(Kaur et al., 2017) was validated by most of the respondents and they provided the feedback that adding software library to a program could achieve interoperability from standardization perspective. ."**Service broker**", "**Service description languages**" and "**Agents for the service description and discovery**"(Bouzerzour et al., 2020) were not validated as enabling factors on technological layer. It could be because of the theoretical nature of these enabling factors, majority of the respondents did not recognize these enabling factors in practical implementation. Another possible reason could be that these elements are more related to "platform owner" of the cloud platform ecosystem and should have been validated by someone from "platform owner" organization. In order to have a conclusive result, further research is recommended.

Organizational dimension

"**Service Level agreement**" was mentioned as an enabling factor in the theoretical framework. In terms of cloud interoperability, four important topics are involved on cloud SLA: architecture, template format, monitoring and SLA objectives (Zhang et al., 2013)."Service Level agreement" was validated by most of the respondents. It was evident from the feedback that SLAs are one of the important enabling factors and is included in the final practical framework.

The interoperability of data

Results on interoperability of data is discussed below, under respective interoperability dimensions.

Conceptual dimension

Trust model which ensures the security of cloud entities in cross-clouds applications(Li & Ping, 2009) was one of the enabling factors mentioned in the theoretical framework. This was positively validated by all the respondents with the comments such as it makes it "*easier to implement secure communication between multiple cloud tenants*" (interview code int_AC2 – 1) and is "*quite beneficial from security perspective of multi cloud application"* (interview code int_AC2 – 2). "**Information interoperability**" which was mentioned as an enabler in the technical framework was positively validated only by three respondents. There were arguments supporting this enabling factor and against this enabling factor during the empirical study. "Information interoperability" seems to be more related to area of business intelligence or data analysis which is a specialized area and further research is needed to provide a conclusive answer about the impact of this enabling factor. Enabling factor "**Platform-independent database abstraction layer**" was not validated. Even though one respondent has mentioned that Platform-independent database abstraction layer can support in avoiding Database vendor lock-in, there seems to be very few practical implementations of this concept. This could be the reason why it was not validated by most of the respondents. "**Data portability**" which was mentioned as another enabling factor was not validated by respondents. Main response from the respondents was that data portability is "*not important for cloud interoperability"* (interview code int_C1) and there are "*intermediary which can do the translation"*(interview code int_C1). Further research is needed to arrive at a conclusive answer due to conflicting feedback from theoretical research and empirical study.

Technological dimension

The enabling factor "**Security**"(Zhang et al., 2013) was validated by all the respondents and was deemed as an important enabling factor. The enabling factor "**Standardized APIs and data models**"(Bouzerzour et al., 2020; Kaur et al., 2017) was also validated by most of the respondents stating that "*Standardized APIs and data models are important for facilitating interoperability between providers"*(interview code int_AC2 – 1)."**Semantic technologies**" that facilitate the exchange and interpretation of data between services(Bouzerzour et al., 2020), which was mentioned as an enabling factor was not validated by respondents. Semantic technologies is a specialized area and further research is needed to provide a conclusive answer as the knowledge of the respondents was limited with respect to this element. Another enabling factor **"Cloud Data Management Interface (CDMI)**"(Kaur et al., 2017) was also not validated possibly due to the limited use of Cloud Data Management Interface (CDMI) in the industry currently and also due to limited knowledge of respondents on this topic.

Organizational dimension

On an organizational layer, the enabling factor "**Data liberation**", which is concerned with giving users control over their data(Toosi et al., 2014) was validated by most of respondents and was included in the practical framework. Some of the insights from the empirical study for this element included "*Exporting the data together with metadata to interpret the data format is important for interoperability of data between applications"* and "*Data security should be considered when exporting/importing data to and from cloud*" (interview code int_AC2 – 1)

5.1.5. Discussion on Design Science research methodology

As realized from the empirical study, the initial theoretical proposition needed to be revised after the conduct of research, by altering the enabling factors in the framework based on feedback. "cloud licensing model"(interview code int_C1), "change management of cloud applications" (interview code int_AC2 – 1) and "governance of interoperable clouds" (interview code int_C3) are some of the enabling factors mentioned as missing in the framework by respondents. In addition "agility to business" (interview code int_AC2 – 1), "digital transformation" (interview code int_AC2 – 2), "competitive edge"(interview code int_C3), "cost-benefit analysis"(interview code int_C4) and "innovation" (interview code int_C4) are mentioned as possible enabling factors by the respondents during the start of the interviews. These additional elements proposed by respondents need to be added to the framework in the form of a second design-evaluation loop according to the Design Science research methodology. However, this will not be conducted due to the limited timeframe of this research as already mentioned in section 3.3

5.1.6. Reflection on validity, reliability, and ethical aspects

A reflection on validity, reliability, and ethical aspects are given in the following section.

Construct validity

We followed a well-defined procedure to gather data, through semi-structured interviews with questions constructed based upon literature found definitions, to ensure the construct validity. After the interviews were conducted, we validated the interview transcripts and asked for additional clarification whenever the feedback from the participants were ambiguous. This improved the construct validity.

Internal validity

We conducted two pilot interviews and refined the interview protocol to improve internal validity. Interviewing people from different background on the same conceptual framework increased internal validity.

External validity

This research only used a single case study, and this could pose a threat to the external validity of the research results, due to the possible lack of generalization to other research settings. The experienced respondents from partner organization and case organizations had several years of experience from different clients and this could minimize the threat to the external validity.

Reliability

In order to increase the reliability, all the steps of the research are described in detail (for instance, we developed an interview protocol and template for data extraction, transcriptions are documented in appendices to enhance the transparency of the research process) and this research can be reproduced by any researcher.

Ethical aspect

On the ethical aspect, by using a consent email we ensured the privacy of those taking part and emphasized the voluntary nature of participation and right to withdraw at any time during the interview.

5.2. Conclusions

As Toosi (Toosi et al., 2014) found out, benefits of an interconnected cloud environment for both cloud providers and their clients are numerous, and there are essential motivations for cloud interoperability. However most new cloud providers propose their own solutions and proprietary interfaces for access to resources and services and this heterogeneity is a crucial problem as it raises barriers to the path of the ubiquitous cloud realization(Toosi et al., 2014). Mezgár (Mezgár & Rauschecker, 2014) mentions that interoperability has huge impact on the cloud adoption in organizations. However, as pointed out by Nodehi (Nodehi, Jardim-Goncalves, Zutshi, & Grilo, 2017), there is still no implicit solution to promote cloud Interoperability. This study aimed to identify factors which enable interoperability of cloud platform ecosystems in organizations, on various interoperability levels such as technical level interoperability, business level interoperability and organizational level interoperability

What are the enabling factors found in the literature, regarding the interoperability of the cloud platform ecosystems?

As part of literature search we found 9 articles, which are selected from 111 assessed articles, that provided a foundation for our research. These articles presented various enabling factors under various dimensions such as interoperability of business, interoperability of processes, interoperability of services and interoperability of data. The enabling factors which are found in the literature are mentioned in Table 2: Theoretical framework of “Enabling factors for cloud interoperability in Enterprises” under section 2.3

How can these enabling factors be integrated into a theoretical framework, which covers various interoperability concerns in enterprises?

In order to integrate the enabling factors into a theoretical framework, it was necessary to define a framework which identifies various interoperability domains. INTEROP NoE framework available in the literature was used as a basis for creating such a framework to integrate the enabling factors. This framework categorized enabling factors into interoperability levels and dimensions, to cover all

interoperability domains.As mentioned previously, the use of INTEROP NoE framework for data extraction was very handy in extracting the information and categorizing the enabling factors to different interoperability domains. Probably the only weakness of this approach was that the use of INTEROP NoE framework resulted in a framework with large number of elements, as it limited the ability to provide a higher order code because elements were placed under various dimensions and domains.

How can the enabling factors identified in the theoretical framework be empirically validated using information from case organization?
We validated these enabling factors by conducting a single case study. We performed interviews with various stakeholders of cloud platform ecosystems to check the relevance of each enabling factor. The results provided empirical evidence on the validity of these enabling factors.

Which of the validated enabling factors are most impactful in practice (i.e., to rank them in terms of relevance, importance)?
Based on the empirical study, below five elements are ranked as the most impactful enabling factors. These factors are positively validated by all the respondents and the empirical results for these elements are inline with literature search.

- Security
- Scalability
- Trust model in cross-clouds applications
- Service Level agreement
- Vendor lock-in avoidance

How can the identified factors influencing interoperability in cloud ecosystems be refined with empirical information?
During the empirical study, it was evident that there is discrepancy between the results of literature search and empirical study. Some of the elements which were not positively validated in empirical study were removed from the theoretical framework before finalizing the practical framework. Some new elements were identified during the empirical study and some of the results from empirical study were inconclusive. A follow-up research is required for finalizing the inconclusive results. A second design-evaluation loop according to the Design Science research methodology is needed to validate the interoperability elements which were newly proposed by respondents during the empirical study.

5.3. Recommendations for practice

The respondents participated in the empirical study mentioned that the framework looks good overall. It was also mentioned that framework covered a lot of areas of enterprise interoperability and that it can be used as a checklist by organization considering cloud interoperability projects, to co-ordinate discussion among various stakeholders. A number of respondents are interested to know about the results of this case study. Once the framework is refined based on further research, it can be used by enterprises which are using cloud applications or considering the move to cloud, to critically think about the possibilities of cloud interoperability and to initiate the discussion on various topics related to enabling factors.

5.4. Recommendations for further research

This research was conducted by one researcher, in one case organization. More research in different case organizations are needed to gain more insights regarding various enabling factors mentioned in

this research. This research followed a Design Science Research Method. This research is only the first design cycle. The results and the discussion of this research provide feedback for a second cycle. As mentioned in the interpretation of results of empirical study (section 5.1.4), there are additional research required to clarify the inconclusive results of some of the enabling factors. Enabling factors such as “Market Platform” and “Aggregator” are not used in the case organization. Additional research in the form of multiple case studies are required to clarify the validity of these elements. Enabling factors such as “Model-driven approach”, “Service broker”, “Service description languages” and “Agents for the service description and discovery” are too technical and theoretical in nature. In order to arrive at a conclusive result regarding whether these are valid enabling factors, a future research with broader research population, including the respondents from “platform owner” who have expert technical knowledge on these topics, would be beneficial. This research has been conducted in a case organization where no interoperability scenarios between the two cloud platform ecosystems area were available yet. Conducting a future research on organizations, which have already available interoperability scenarios between the two cloud platform ecosystems, could provide additional viewpoints.

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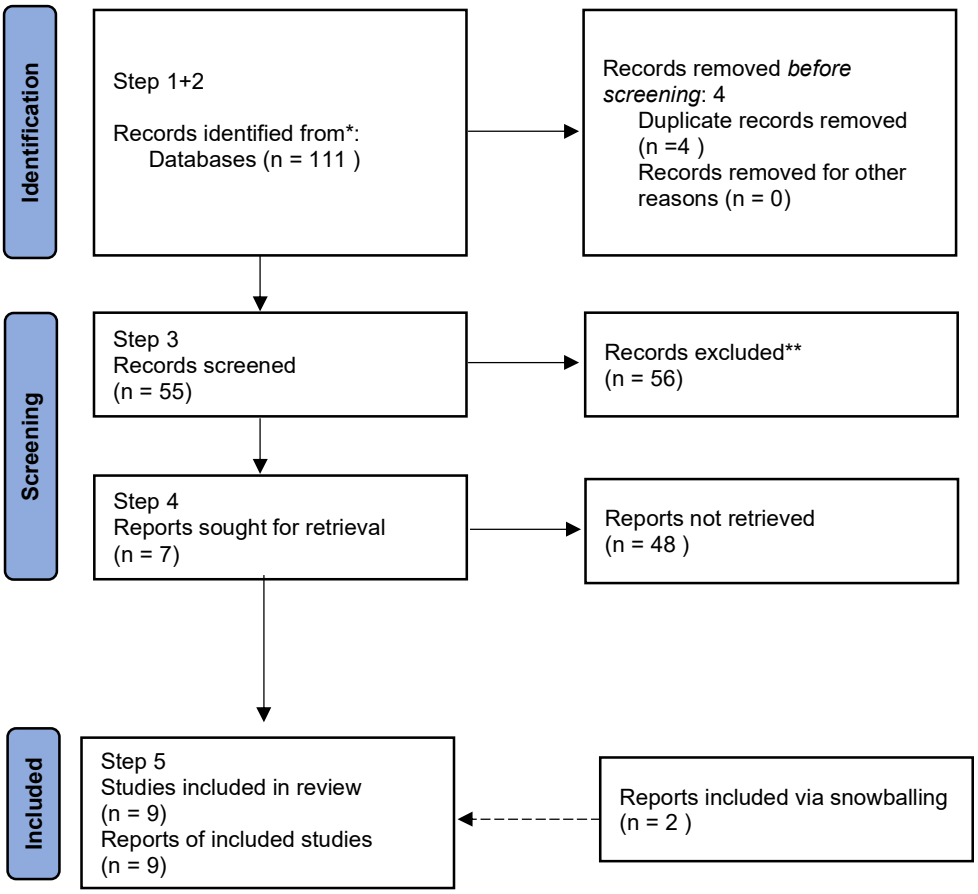
Appendix A Article selection strategy



The PRISMA flowchart (Moher, Liberati, Tetzlaff, Altman, & Group, 2009) which is used as the selection strategy for articles.

Appendix B Literature review

Article number	Description	Cloud platform ecosystem	interop erability	selected based on abstract	Full paper available	non-technical
1.	Chopra: interoperability needed for cloud computing success. 2009, Aspen Publishers, Inc: Washington. p. 7.	0	0	0	0	0
2.	Businesses back interoperability in the cloud. 2010.	0	0	0	0	0
3.	Oracle Announces Cloud Based APIs for Interoperability 310641. 2010.	0	0	0	0	0
4.	Apache Deltacloud 10 Supports OpenSource Cloud Interoperability 613046. 2012.	0	0	0	0	0
5.	Afsari, K., C. Eastman, and D. Shelden, Building Information Modeling data interoperability for Cloud-based collaboration: Limitations and opportunities. International journal of architectural computing, 2017. 15(3): p. 187-202.	0	0	0	0	0
6.	Akherfi, K., H. Harroud, and M. Gerndt, A Mobile Cloud Middleware to Support Mobility and Cloud Interoperability. International journal of adaptive, resilient, and autonomic systems, 2016. 7(1): p. 41-58.	1	1	1	0	0
7.	Amato, F., et al. A Framework for Semantic Interoperability over the Cloud. IEEE.	1	1	1	0	0
8.	Avgeriou, P. and U. Zdun, Software Architecture: 8th European Conference, ECSA 2014, Vienna, Austria, August 25-29, 2014, Proceedings. Vol. 8627. 2014, Cham: Springer International Publishing AG.	0	0	0	0	0
9.	Bachoumis, A., et al., Cloud-Edge Interoperability for Demand Response-Enabled Fast Frequency Response Service Provision. IEEE transactions on cloud computing, 2021: p. 1-1.	0	0	0	0	0
10.	Bacso, G., et al., On Efficiency of Multi-job Grid Allocation Based on Statistical Trace Data: Cloud Interoperability and Cloud Federation. Journal of grid computing, 2014. 12(1): p. 169-186.	0	0	0	0	0
11.	Baird, S. Heterogeneity and interoperability at the core: SOA, virtualization, the cloud and the government role. ACM.	0	1	0	0	0

12.	Balamurugan, B., et al. Common Cloud Architecture for Cloud Interoperability. ACM.	1	1	1	1	0
13.	Bernstein, D. Keynote 2: The Intercloud: Cloud Interoperability at Internet Scale. IEEE.	1	1	1	0	0
14.	Bernstein, D., et al. Blueprint for the Intercloud - Protocols and Formats for Cloud Computing Interoperability. IEEE.	1	1	1	0	0
15.	Borck, J.R. ENTERPRISE STRATEGIES: Head in the clouds - Sun's failure to participate in the WS-I does little to instill confidence in Web services interoperability. 2002. 24, 50.	0	1	0	0	0
16.	Bouzerzour, N.E.H., S. Ghazouani, and Y. Slimani, A survey on the service interoperability in cloud computing: Client-centric and provider-centric perspectives. Software, practice & experience, 2020. 50(7): p. 1025-1060.	1	1	1	1	1
17.	Brodkin, J. Cloud computing needs better security, interoperability to live up to hype; New vendor groups tackle lingering issues related to cloud computing. 2009. 1-1.	1	1	1	0	0
18.	Brodkin, J. Xen.org aims for the cloud with open source initiative; Virtual machine interoperability a major goal for Xen Cloud Platform. 2009.	1	1	1	0	0
19.	Brodkin, J. VMware's SpringSource boosts cloud computing plans with acquisition; Purchase of Rabbit Technologies could improve interoperability in the cloud. 2010.	0	0	0	0	0
20.	Brown, B. Cloud computing, virtualization proponents getting antsy; Cloud service interoperability, virtualization of mission critical apps among next big things. 2009.	1	1	1	0	0
21.	Butler, B. HP cloud plans focus on open source, management; HP's Converged Cloud model will depend on interoperability with hardware from other vendors. 2012.	1	1	1	0	0
22.	Butler, B. BSA: The world is not yet cloud friendly; Japan judged tops in the world for cloud interoperability, emerging countries last. 2012.	1	1	1	0	0
23.	Butler, B. Efforts afoot to advance cloud standards; The fight for interoperability in the cloud could rest on the evolution of standards. 2012.	1	1	1	0	0

24.	Castañé, G.G., et al., An ontology for heterogeneous resources management interoperability and HPC in the cloud. Future generation computer systems, 2018. 88: p. 373-384.	1	1	1	1	0
25.	Cesario, E., C. Mastroianni, and D. Talia, A Multi-Domain Architecture for Mining Frequent Items and Itemsets from Distributed Data Streams: Cloud Interoperability and Cloud Federation. Journal of grid computing, 2014. 12(1): p. 153-168.	0	1	0	0	0
26.	Chadwick, D.W., et al., Adding Federated Identity Management to OpenStack: Cloud Interoperability and Cloud Federation. Journal of grid computing, 2014. 12(1): p. 3-27.	1	1	1	1	0
27.	Charalabidis, Y., M. Janssen, and O. Glassey. Introduction to Cloud Infrastructures and Interoperability Minitrack. IEEE.	1	1	0	0	0
28.	Di Martino, B., Applications Portability and Services Interoperability among Multiple Clouds. IEEE cloud computing, 2014. 1(1): p. 74-77.	1	1	1	0	0
29.	Di Martino, B., G. Cretella, and A. Esposito. Semantic and Agnostic Representation of Cloud Patterns for Cloud Interoperability and Portability. IEEE.	1	1	1	0	0
30.	Di Martino, B., G. Cretella, and A. Esposito, Advances in Applications Portability and Services Interoperability among Multiple Clouds. IEEE cloud computing, 2015. 2(2): p. 22-28.	1	1	1	0	0
31.	Emeakaroha, V.C., et al., Cloud Interoperability via Message Bus and Monitoring Integration. Springer Berlin Heidelberg: Berlin, Heidelberg. p. 65-74.	1	1	1	1	0
32.	Fabra, J., et al., Solving the Interoperability Problem by Means of a Bus: An Experience on the Integration of Grid, Cluster and Cloud Infrastructures. Journal of grid computing, 2013. 12(1): p. 41-65.	0	1	0	0	0
33.	Fabra, J., et al., Solving the Interoperability Problem by Means of a Bus: An Experience on the Integration of Grid, Cluster and Cloud Infrastructures: Cloud Interoperability and Cloud Federation. Journal of grid computing, 2014. 12(1): p. 41-65.	1	1	1	1	0

34.	Ferreira, L., et al., Dashboard Services for Pragmatics-Based Interoperability in Cloud and Ubiquitous Manufacturing. International journal of web portals, 2014. 6(1): p. 35-49.	1	0	0	0	0
35.	Field, L., et al., The EMI Registry: Discovering Services in a Federated World: Cloud Interoperability and Cloud Federation. Journal of grid computing, 2014. 12(1): p. 29-40.	1	1	1	1	0
36.	Gallant, J. SUSE Linux top exec: Interoperability is key; In an exclusive interview, SUSE president and GM Nils Brauckmann talks about strategic partnerships, building clouds, and whether the economic downturn presents an opportunity for open source. 2011.	1	0	0	0	0
37.	Garakanidze, A., Moving Data to Enterprise Clouds: Data clouds reduce cost and complexity of storing data, but introduce latency and migration challenges; virtualization can help ensure continuous interoperability. Information Management, 2009. 19: p. 12.	1	0	0	0	0
38.	Garcia-Penalvo, F.J., M. Alier Forment, and M.D. Lytras, Some Reflections about Service Oriented Architectures, Cloud Computing Applications, Services and Interoperability J.UCS Special Issue. J.UCS (Annual print and CD-ROM archive ed.), 2012. 18(11): p. 1405-1409.	1	1	1	0	0
39.	Goozner, M. Heads in the cloud. Health IT's failure to achieve interoperability invites congressional scrutiny. 2013. 43, 24-0024.	0	1	0	0	0
40.	Gracia-Tinedo, R., et al., Giving wings to your data: A first experience of Personal Cloud interoperability. Future generation computer systems, 2018. 78: p. 1055-1070.	1	1	1	1	0
41.	Gürsel, E. and A. Tarek. Analysis Of Interoperability In Cloud Computing. ACM.	1	1	1	1	0
42.	Haughton, J. Look up: the right EHR may be in the cloud. Major advantages include interoperability and flexibility. 2011. 32, 52-52.	0	1	0	0	0

43.	Hernández, R., C. Gütl, and H.R. Amado-Salvatierra, Using JSON-LD and Hydra for Cloud-Based Tool Interoperability: A Prototype Based on a Vocabulary and Communication Process Handler for Mind Map Tools. Springer International Publishing: Cham. p. 428-433.	0	1	0	0	0
44.	Hernandez Rizzardini, R., Cloud Interoperability Service Architecture for Education Environments. J.UCS (Annual print and CD-ROM archive ed.), 2015. 21(5): p. 656-678.	0	1	0	0	0
45.	Hernandez Rizzardini, R., et al., Cloud Services, Interoperability and Analytics within a ROLE-enabled Personal Learning Environment. 2013, Verlag der Technischen Universität Graz: GRAZ. p. 2054-2074.	0	1	0	0	0
46.	Hettick, L. Alliance pursues HD interoperability: Cloud Communications Alliance's goal is to 'drive development and adoption of the first nationwide high-definitionenterprise voice and data network in the IP cloud'. 2010.	0	1	0	0	0
47.	Hettick, L. Alliance pursues HD interoperability; Cloud Communications Alliance's goal is to 'drive development and adoption of the first nationwide high-definition enterprise voice and data network in the IP cloud'. 2010.	0	1	0	0	0
48.	Hodicky, J., Modelling and Simulation for Autonomous Systems: First International Workshop, MESAS 2014, Rome, Italy, May 5-6, 2014, Revised Selected Papers. Vol. 8906. 2015, Cham: Springer International Publishing AG.	0	0	0	0	0
49.	Huang, W.-C. and W. Knottenbelt. Self-Adaptive Containers: Interoperability Extensions and Cloud Integration. IEEE.	1	0	0	0	0
50.	Ilijašić Veršić, I. and J. Ausserhofer, Social sciences, humanities and their interoperability with the European Open Science Cloud: What is SSHOC? Mitteilungen der Vereinigung Österreichischer Bibliothekarinnen & Bibliothekare, 2019. 72(2): p. 383-391.	0	0	0	0	0
51.	Janssen, M., Y. Charalabidis, and H. Krcmar. Introduction to Cloud Infrastructures and Interoperability Minitrack. IEEE.	1	1	1	0	0

52.	Kamateri, E., et al., Cloud4SOA: A Semantic-Interoperability PaaS Solution for Multi-cloud Platform Management and Portability. Springer Berlin Heidelberg: Berlin, Heidelberg. p. 64-78.	1	1	1	1	0
53.	Kaur, K., D.R. Sharma, and D.R. Kahlon, Interoperability and Portability Approaches in Inter-Connected Clouds: A Review. ACM computing surveys, 2017. 50(4): p. 1-40.	1	1	1	1	1
54.	Khalfallah, M., et al., A cloud-based platform to ensure interoperability in aerospace industry. Journal of intelligent manufacturing, 2014. 27(1): p. 119-129.	0	1	0	0	0
55.	Kurosu, M., Human-Computer Interaction: Applications and Services: 15th International Conference, HCI International 2013, Las Vegas, NV, USA, July 21-26, 2013, Proceedings, Part II. Vol. 8005. 2013: Springer.	0	1	0	0	0
56.	Labrador, H.G., et al. Increasing interoperability for research clouds: CS3APIs for connecting sync&share storage, applications and science environments. Les Ulis: EDP Sciences.	0	1	0	0	0
57.	Lau, K.-K., W. Lamersdorf, and E. Pimentel, Service-Oriented and Cloud Computing: Second European Conference, ESOCC 2013, Málaga, Spain, September 11-13, 2013, Proceedings. Vol. 8135. 2013, Berlin, Heidelberg: Springer Berlin / Heidelberg.	0	0	0	0	0
58.	Lengauer, C., et al., Euro-Par 2014: Parallel Processing Workshops: Euro-Par 2014 International Workshops, Porto, Portugal, August 25-26, 2014, Revised Selected Papers, Part II. Vol. 8806. 2014: Springer International Publishing.	1	1	1	1	0
59.	Levin, A., et al. Networking Architecture for Seamless Cloud Interoperability. IEEE.	1	1	1	0	0
60.	Lewis, G.A. Role of Standards in Cloud-Computing Interoperability. IEEE.	1	1	1	0	0
61.	Li, W. and L. Ping, Trust Model to Enhance Security and Interoperability of Cloud Environment. Springer Berlin Heidelberg: Berlin, Heidelberg. p. 69-79.	1	1	1	1	1

62.	Lordan, F., et al., ServiceSs: An Interoperable Programming Framework for the Cloud: Cloud Interoperability and Cloud Federation. Journal of grid computing, 2014. 12(1): p. 67-91.	1	1	1	1	0
63.	Loutas, N., et al. Cloud Computing Interoperability: The State of Play. IEEE.	1	1	1	0	0
64.	Loutas, N., E. Kamateri, and K. Tarabanis. A Semantic Interoperability Framework for Cloud Platform as a Service. IEEE.	1	1	1	0	0
65.	Ludäscher, B. and B. Plale, Provenance and Annotation of Data and Processes: 5th International Provenance and Annotation Workshop, IPAW 2014, Cologne, Germany, June 9-13, 2014. Revised Selected Papers. Vol. 8628. 2015, Cham: Springer International Publishing AG.	0	0	0	0	0
66.	Ma, H., et al., A formal model for the interoperability of service clouds. Service oriented computing and applications, 2012. 6(3): p. 189-205.	1	1	1	1	0
67.	Marozzo, F., et al., Enabling Cloud Interoperability with COMPSs. Springer Berlin Heidelberg: Berlin, Heidelberg. p. 16-27.	1	1	1	1	0
68.	McCullagh, R. Developing a natioal smart ticketing programme: London's oyster card is long established, but the roll-out of smart ticketing to rail services across the country has so far made limited progress. The introduction of common standards and the development of mobile and cloud-based technologies means that greater interoperability between modes and regions is now in prospect. 2014. 170, 59.	0	0	0	0	0
69.	Meersman, R., et al., On the Move to Meaningful Internet Systems: OTM 2014 Workshops: Confederated International Workshops: OTM Academy, OTM Industry Case Studies Program, C&TC, EI2N, INBAST, ISDE, META4eS, MSC and OnToContent 2014, Amantea, Italy, October 27-31, 2014. Proceedings. Vol. 8842. 2014: Springer.	0	0	0	0	0
70.	Merzky, A., K. Stamou, and S. Jha. Application Level Interoperability between Clouds and Grids. IEEE.	0	1	0	0	0
71.	Mezgár, I. and U. Rauschecker, The challenge of networked enterprises for cloud computing interoperability. Computers in industry, 2014. 65(4): p. 657-674.	1	1	1	1	1

72.	Mikkilineni, R. WETICE 2010 2nd Workshop on Collaboration and Cloud Computing (CCC) Theme: Computing Clouds with Telecom Grade "Trust" and Global Interoperability. IEEE.	1	1	1	0	0
73.	Mladenic, D., et al., The semantic web: ESWC 2012 Satellite Events : ESWC 2012 Satellite Events, Heraklion, Crete, Greece, May 27-31, 2012. Revised selected papers. Vol. 7540. 2015: Springer.	0	0	0	0	0
74.	Mourad, M.H., et al., Assessment of interoperability in cloud manufacturing. Robotics and computer-integrated manufacturing, 2020. 61: p. 101832.	0	1	0	0	0
75.	Nguyen, T. and S. Ngo. Semantic Cubing Platform enabling Interoperability Analysis among Cloud-based Linked Data Cubes. ACM.	0	1	0	0	0
76.	Nodehi, T., S. Ghimire, and R. Jardim-Goncalves. Toward a unified intercloud interoperability conceptual model for IaaS cloud service. SCITEPRESS.	1	1	1	0	0
77.	Nodehi, T., et al., ICIF: an inter-cloud interoperability framework for computing resource cloud providers in factories of the future. International journal of computer integrated manufacturing, 2017. 30(1): p. 147-157.	0	0	0	0	0
78.	Parak, B. and Z. Sustr. Challenges in Achieving IaaS Cloud Interoperability across Multiple Cloud Management Frameworks. IEEE Computer Society.	1	1	1	0	0
79.	Pedone, G. and I. Mezgár, Model similarity evidence and interoperability affinity in cloud-ready Industry 4.0 technologies. Computers in industry, 2018. 100: p. 278-286.	0	0	0	0	0
80.	Petcu, D., Portability and Interoperability between Clouds: Challenges and Case Study: Invited Paper. Springer Berlin Heidelberg: Berlin, Heidelberg. p. 62-74.	1	1	1	1	1
81.	Pflanzner, T. and A. Kertesz, Towards Data Interoperability of Cloud Infrastructures Using Cloud Storage Services. Springer Berlin Heidelberg: Berlin, Heidelberg. p. 85-94.	0	1	0	0	0

82.	Pontes Guimaraes, F., et al., A Framework for Adaptive Fault-Tolerant Execution of Workflows in the Grid: Empirical and Theoretical Analysis: Cloud Interoperability and Cloud Federation. Journal of grid computing, 2014. 12(1): p. 127-151.	0	0	0	0	0
83.	Postół, M. and P. Szymczak, Object-Oriented Internet Cloud Interoperability. 2021, Springer International Publishing: Cham. p. 568-581.	0	1	0	0	0
84.	Pramukantoro, E.S. and F.A. Bakhtiar, Cloud-based Middleware for Syntactical Interoperability in Internet of Things. Journal of Information Technology and Computer Science, 2020. 5(1): p. 32-37.	0	1	0	0	0
85.	Ramalingam, C. and P. Mohan, Addressing Semantics Standards for Cloud Portability and Interoperability in Multi Cloud Environment. Symmetry (Basel), 2021. 13(2): p. 317.	1	1	1	1	0
86.	Ramalingam, C. and P. Mohan, An Efficient Applications Cloud Interoperability Framework Using I-Anfis. Symmetry (Basel), 2021. 13(2): p. 268.	1	1	1	1	0
87.	Ranjan, R., The Cloud Interoperability Challenge. IEEE cloud computing, 2014. 1(2): p. 20-24.	1	1	1	0	0
88.	Rezaei, R., et al., A semantic interoperability framework for software as a service systems in cloud computing environments. Expert systems with applications, 2014. 41(13): p. 5751-5770.	1	1	1	1	0
89.	Rizzardini, R., C. Gütl, and H. Amado-Salvatierra. Interoperability for cloud-based applications for education settings based on JSON-LD and Hydra: ontology and a generic vocabulary for mind map tools. ACM.	1	1	1	1	0
90.	Rizzardini, R.H., Cloud Interoperability Service Architecture for Education Environments. 2015, Verlag der Technischen Universität Graz.	1	1	1	0	0
91.	Salem, A.A., et al., Microstructure-Informed Cloud Computing for Interoperability of Materials Databases and Computational Models: Microtextured Regions in Ti Alloys. Integrating materials and manufacturing innovation, 2017. 6(1): p. 111-126.	0	1	0	0	0

92.	Salem, A.A., et al., Microstructure-Informed Cloud Computing for Interoperability of Materials Databases and Computational Models: Microtextured Regions in Ti. Integrating materials and manufacturing innovation, 2017. 6(1): p. 111-126.	0	1	0	0	0
93.	Sehgal, S., et al., Understanding application-level interoperability: Scaling-out MapReduce over high-performance grids and clouds. Future generation computer systems, 2011. 27(5): p. 590-599.	0	1	0	0	0
94.	Selvanathan, N., D. Jayakody, and V. Damjanovic-Behrendt. Federated Identity Management and Interoperability for Heterogeneous Cloud Platform Ecosystems. ACM.	1	1	1	1	0
95.	Sill, A. and G. Kecskemeti, Guest Editors' Introduction: Special Issue on Interoperability, Federation Frameworks and Application Programming Interfaces for IaaS Clouds. Journal of grid computing, 2014. 12(1): p. 1-2.	1	1	1	1	0
96.	Sill, A. and G. Kecskemeti, Cloud Interoperability and Cloud Federation. Journal of grid computing, 2014. 12(1).	1	1	0	0	0
97.	Sluijs, J.P.J.B., P. Larouche, and W. Sauter, Cloud computing in the EU policy sphere interoperability, vertical integration and the internal market. JIPITEC, 2012. 3(1): p. 12-32.	1	0	0	0	0
98.	Song, S., Competition law and interoperability in cloud computing. The computer law and security report, 2017. 33(5): p. 659-671.	1	1	0	0	0
99.	Sutherland, S., Convergence of Interoperability of Cloud Computing, Service Oriented Architecture and Enterprise Architecture. International journal of e-entrepreneurship and innovation, 2013. 4(1): p. 43-51.	1	1	1	0	0
100.	Tao, M., et al., Hybrid Cloud Architecture for Cross-Platform Interoperability in Smart Homes. 2018, Springer International Publishing: Cham. p. 608-617.	0	1	0	0	0
101.	Teckelmann, R., C. Reich, and A. Sulistio. Mapping of Cloud Standards to the Taxonomy of Interoperability in IaaS. IEEE.	1	1	1	0	0

102.	TrÖGer, P. and A. Merzky, Towards Standardized Job Submission and Control in Infrastructure Clouds: Cloud Interoperability and Cloud Federation. Journal of grid computing, 2014. 12(1): p. 111-125.	1	0	0	0	0
103.	Truong, H.-L., L. Gao, and M. Hammerer. Service architectures and dynamic solutions for interoperability of IoT, network functions and cloud resources. ACM.	1	1	1	1	0
104.	Ünver, M.B., What cloud interoperability connotates for EU policy making: Recurrence of old problems or new ones looming on the horizon? Telecommunications policy, 2019. 43(2): p. 154-170.	1	1	1	1	1
105.	Wang, X.V., L. Wang, and R. Gördes, Interoperability in cloud manufacturing: a case study on private cloud structure for SMEs. International journal of computer integrated manufacturing, 2018. 31(7): p. 653-663.	0	1	0	0	0
106.	Wong, W.K., et al. Secure query processing with data interoperability in a cloud database environment. ACM.	0	1	0	0	0
107.	Wyrzykowski, R., et al., Parallel Processing and Applied Mathematics: 12th International Conference, PPAM 2017, Lublin, Poland, September 10-13, 2017, Revised Selected Papers, Part II. 2018, Cham: Springer International Publishing AG.	0	0	0	0	0
108.	Yangui, S., et al., CompatibleOne: The Open Source Cloud Broker: Cloud Interoperability and Cloud Federation. Journal of grid computing, 2014. 12(1): p. 93-109.	1	1	1	1	0
109.	Yongsiriwit, K., M. Sellami, and W. Gaaloul. A Semantic Framework Supporting Cloud Resource Descriptions Interoperability. IEEE.	1	1	1	0	0
110.	Zhang, Z., C. Wu, and D.W.L. Cheung, A survey on cloud interoperability: taxonomies, standards, and practice. Performance evaluation review, 2013. 40(4): p. 13-22.	1	1	1	1	1
111.	Zhuravlev, E.E., et al., Aspects of methodology of ensuring interoperability in the Gridenvironment and cloud computing. Computer Research and Modeling, 2015. 7(3): p. 675-682.	0	1	0	0	0

Appendix C Literature review snowballing

Reference articles used for snowballing	Backward snowballing result
Kaur, K., D.R. Sharma, and D.R. Kahlon, Interoperability and Portability Approaches in Inter-Connected Clouds: A Review. ACM computing surveys, 2017. 50(4): p. 1-40.	Toosi, A. N., Calheiros, R. N., & Buyya, R. (2014). Interconnected cloud computing environments: Challenges, taxonomy, and survey. ACM Computing Surveys (CSUR), 47(1), 1-47.
Petcu, D., Portability and Interoperability between Clouds: Challenges and Case Study: Invited Paper. Springer Berlin Heidelberg: Berlin, Heidelberg. p. 62-74.	Oberle, K., & Fisher, M. (2010, August). ETSI CLOUD–initial standardization requirements for cloud services. In International Workshop on Grid Economics and Business Models (pp. 105-115). Springer, Berlin, Heidelberg.

Appendix D Data Extraction

General information 1

Title of the article	A survey on the service interoperability in cloud computing: Client-centric and provider-centric perspectives. Software, practice & experience.
Author(s)	Bouzerzour, N.E.H., S. Ghazouani, and Y. Slimani
Year of publication	2020

Relevance and review questions

Subject	Answer (Yes/ No)	Argumentation
Are the research objectives close to our own?	Yes	Propose a taxonomy to classify the cloud interoperability approaches into client-centric and provider-centric categories.
Is the context like our own?	Yes	
Is this article used as a reference in other articles?	Yes	
Does the article provide guidance for future research?	Yes	
Does the article discuss about interoperability of business, process, services or data?	Yes	Service interoperability Data interoperability

Does the article discuss about factors enabling cloud interoperability?	Yes	
Is the study sufficiently generic?	Yes	
Is the study's methodology sufficient?	Yes	

Extraction

Interoperability dimensions	Interoperability levels	Enabling factors	Main findings
conceptual	Business		
	Process		
	Service	Standardization, brokering, model-driven approaches and semantic-based solutions. multiple agents for the service description and discovery	
	Data	platform-independent database abstraction layer	
Technological	Business		
	Process	model-driven engineering (MDE) cloud modeling framework (CloudMF),and cloud modeling language (CloudML) Microservices - An application development approach, in which an application is developed as a group of small modular services that communicated with each other	model-driven engineering (MDE) methods and techniques are the best to manage the complexity of multicloud systems development and administration. They proposed cloudmodeling framework (CloudMF) and cloud modeling language (CloudML)
	Service	Middleware intermediate the communication between distributed applications	

		SOA A set of services that are provided at a network address and that are published, discovered and invoked over the web. Service description languages A language that enables the description of services functionalities, properties	
	Data	Semantic technologies facilitate the exchange and interpretation of data between services Common data models - A standard format to which heterogeneous data is transformed and that allows the data comparison	
Organizational	Business		
	Process		
	Service		
	Data		
Additional findings	General		There are five major cloud actors that were described in the cloud computing reference architecture: cloud consumer, cloud provider, cloud broker, cloud auditor, and cloud carrier. From the literature, we notice that the proposed solutions target two cloud actors: (i) cloud consumer, which we refer to as “cloud client” in the current survey; and (ii) cloud provider. •Intramodel interoperability is highly addressed because the interoperability between services of the same delivery model (eg, SaaS-SaaS, IaaS-IaaS) is essential for an efficient service delivery over the cloud. This interoperability provides more instances for the data processing. Consequently, it decreases the load on each computation instance by distributing the initial load on several nodes. This enables the cloud to handle the traffic effectively and it reduces the downtime. However,

			intramodel interoperability is also a drawback because it does not guarantee interoperability with other delivery models. • Intermodel interoperability, in the other hand, enables interoperability between services of different delivery models (eg, PaaS-IaaS, SaaS-PaaS), which gives the clients a range of choices over which platform and infrastructure to run or deploy their applications on. Besides, when services require more resources (eg, CPU, RAM) the intermodel interoperability will enable vertical scaling to acquire more capacity. • Organizations are reluctant to adopt cloud solutions because they may be unable to make heterogeneous smanagement and planning applications (eg, CRM, ERP) interoperate due to the lack of SaaS interoperability solutions. • Cloud providers are the main cause for the lack of interoperable SaaS solutions because they focus on the added-value of their software. Therefore, they offer customized services compared with competitors' services. The lack of standardization may unwillingly lock-in clients to one provider, even though better services (in regards to QoS and cost) may exist, which prevents the fair competition in the cloud market.

General information 2

Title of the article	Interoperability and portability approaches in inter-connected clouds: A review. ACM Computing Surveys (CSUR), 50(4), 1-40.
Author(s)	Kaur, K., Sharma, D. S., & Kahlon, D. K. S.
Year of publication	2017

Relevance and review questions

Subject	Answer (Yes/ No)	Argumentation

Are the research objectives close to our own?	Yes	Extensive literature review by surveying more than 120 papers has been done to analyze and categorize various solutions suggested in literature for solving the interoperability issues of inter-connected clouds.
Is the context like our own?	Yes	
Is this article used as a reference in other articles?	Yes	
Does the article provide guidance for future research?	Yes	
Does the article discuss about interoperability of business, process, services or data?	Yes	Business interoperability Process interoperability Service interoperability Data interoperability
Does the article discuss about factors enabling cloud interoperability?	Yes	
Is the study sufficiently generic?	Yes	
Is the study's methodology sufficient?	Yes	

Extraction

Interoperability dimensions	Interoperability levels	Enabling factors	Main findings
conceptual	Business	Vendor lock-in avoidance	If interoperability is enabled in inter-connected clouds, the cloud users can easily migrate elsewhere for better Quality of Service (QoS) and cost which would overcome the fear of being trapped with some provider
	Process	Formulating standards for cloud computing is the most obvious solution for achieving interoperability and portability in Inter-clouds. A lot of efforts are devoted by cloud standardization projects for the development of standards for clouds covering the aspects concerned with development, deployment, security, management, storage, and so forth.	
	Service		

	Data		
Technological	Business		
	Process		
	Service	Open libraries and Open services which rely on the use of abstraction layers and adapters	Open libraries or client side libraries can be used to implement cross-platform APIs which help to overcome the vendor lock-in problem. These libraries offer a unified interface to users which can abstract disparate providers' API features, services, and cloud management technologies
	Data	Standardized APIs and data models are the two solutions which are usually suggested for achieving semantic interoperability Considered as the storage backbone in cloud interoperability, CDMI defines the final interface which can be used by application to carry out CRUD operations in the cloud	
Organizational	Business		
	Process	Various Cloud Computing Standardization Organizations	
	Service		
	Data		
Additional findings	General		The interoperability issue concerns cloud vendors and the portability issue concerns both the providers and the customers Standards should be created with flexibility and extensibility in mind, taking into account that cloud computing evolves at a very fast pace Some prominent EU funded projects based on semantics are as follows: —mOSAIC (Petcu et al. 2013). —Cloud4SOA (Kamateri et al. 2013, D'Andria et al. 2012).

			Challenges in inter-connected clouds : Provisioning. SLA. Security Monitoring Network Performance Autonomics.

General information 3

Title of the article	The challenge of networked enterprises for cloud computing interoperability. Computers in Industry, 65(4), 657-674.
Author(s)	Mezgár, I., & Rauschecker, U.
Year of publication	2020

Relevance and review questions

Subject	**Answer (Yes/ No)**	**Argumentation**
Are the research objectives close to our own?	Yes	Paper discusses about cloud interoperability in networked enterprises
Is the context like our own?	Yes	
Is this article used as a reference in other articles?	Yes	
Does the article provide guidance for future research?	Yes	
Does the article discuss about interoperability of business, process, services or data?	Yes	Business interoperability Process interoperability Service interoperability Data interoperability
Does the article discuss about factors enabling cloud interoperability?	Yes	
Is the study sufficiently generic?	Yes	
Is the study's methodology sufficient?	Yes	

Extraction

Interoperability dimensions	Interoperability levels	Enabling factors	Main findings
conceptual	Business	Networked enterprises - Enterprise architectures of this kind are, e.g. the collaborative enterprise, digital enterprise, smart organization, extended enterprise, virtual enterprise. Achieving high efficiency in intra- and interorganizational value/supply chains Semantic interoperability and Seamless integration of entities within (intra) and outside (inter) the enterprises (e.g. suppliers, business partners, employees, workers, customers) Collaborative modelling	The collaboration and cooperation are main characteristics of networked enterprises Members of a VE are changing frequently, its organization structure is highly flexible. Originating from the frequent organizational changes their IT systems must be able to follow the demand of the new VE members. This means that new IT systems are involved frequently into the VE, so the interoperability is a continuous challenge for the IT system of a VE enable enterprises to interact with other entities within (intra) and outside (inter) the enterprises (e.g. suppliers, business partners, employees, workers, customers) in a seamless way
	Process	Alignment of cross organizational business process support business process operations like distributed business processes, business-to-business integration.	Cross organizational business process, in NEs integrate different internal processes into a common one EI mostly means connecting computer systems and IT applications to support business process operations like distributed business processes, business-to-business integration. Interoperability possibilities are embedded into this environment on different levels, in different ways as a vital element of the joint operation.
	Service		
	Data	Information interoperability – to make query languages and different data models working together	
Technological	Business		
	Process		

	Service		
	Data		
Organizational	Business		
	Process		
	Service		
	Data		
Additional findings	General		General advantages of cloud computing are the massive scale, the homogeneity, the virtualization, resilient computing, low cost software, geographical distribution, service orientation and advanced central security technologies. Interoperability and standardization have huge impact on the cloud adoption and usage. Standardization will increase and accelerate the adoption of cloud computing as users will have a wider range of choices in cloud without vendor lock-in, portability and ability to use the cloud services provided by multiple vendors. ''The greatest challenge facing longer term adoption of cloud computing services is not security, but rather cloud interoperability and data portability'' say cloud computing experts from IEEE

General information 4

Title of the article	Portability and interoperability between clouds: challenges and case study. In European conference on a service-based internet (pp. 62-74). Springer, Berlin, Heidelberg.
Author(s)	Petcu, D.
Year of publication	2011

Relevance and review questions

Subject	Answer (Yes/ No)	Argumentation
Are the research objectives close to our own?	Yes	Concepts and approaches of interoperability between clouds
Is the context like our own?	Yes	
Is this article used as a reference in other articles?	Yes	
Does the article provide guidance for future research?	Yes	
Does the article discuss about interoperability of business, process, services or data?	Yes	Business interoperability Process interoperability Service interoperability Data interoperability
Does the article discuss about factors enabling cloud interoperability?	Yes	
Is the study sufficiently generic?	Yes	
Is the study's methodology sufficient?	Yes	

Extraction

Interoperability dimensions	Interoperability levels	Enabling factors	Main findings
conceptual	Business	Market: economic models driven optimization techniques; market driven resource leasing federation – application service providers host their services based on negotiated SLAs driven by competitive market prices; flexible mapping of services to resources to maximize efficiency, cost-effectiveness, and utilization; accounting; license flexibility.	
	Process	Deployment: provision resources from multiple cloud services with a single management	

		tool; agreements between providers; service discovery; common platforms to ensure users can navigate between services/applications; enabling a service hosted on one platform to automatically call a service hosted by another;	
	Service	programming: move from one provider to another without dramatic reimplementation; common set of interfaces; standard API enabling an entity to build something once, then use it to monitor and control a variety of platforms;	
	Data		
Technological	Business		
	Process		
	Service		
	Data		
Organizational	Business		
	Process		
	Service		
	Data		
Additional findings	General		deployment scenarios in multiple clouds: Serially, one cloud at a time, with three scenarios: (a) migration between clouds; (b) interface across multiple clouds; (c) work with a selected cloud; Simultaneously, several clouds at a time, when operate across multiple clouds.

General information 5

Title of the article	Interconnected cloud computing environments: Challenges, taxonomy, and survey. ACM Computing Surveys (CSUR), 47(1), 1-47.
Author(s)	Toosi, A. N., Calheiros, R. N., & Buyya, R.

Year of publication	2014

Relevance and review questions

Subject	**Answer (Yes/ No)**	**Argumentation**
Are the research objectives close to our own?	Yes	Discusses all the relevant aspects motivating cloud interoperability. Furthermore, it categorizes and identifies possible cloud interoperability scenarios and architectures.
Is the context like our own?	Yes	
Is this article used as a reference in other articles?	Yes	
Does the article provide guidance for future research?	Yes	
Does the article discuss about interoperability of business, process, services or data?	Yes	Business interoperability Process interoperability Service interoperability Data interoperability
Does the article discuss about factors enabling cloud interoperability?	Yes	
Is the study sufficiently generic?	Yes	
Is the study's methodology sufficient?	Yes	

Extraction

Interoperability dimensions	Interoperability levels	Enabling factors	Main findings
conceptual	Business	Growth in the scale of existing applications or surge in demand for a service Avoiding Vendor Lock-In	Even though one of the key features of cloud computing is the illusion of infinite resources,capacity in cloud providers' data centers is limited and eventually can be fully utilized [Calheiros et al. 2012a; Aoyama and Sakai 2011]. Growth in the scale of existing applications or surge in demand for a service may result in immediate need for additional capacity in the data

		Utilizing multiple clouds at the same time is the only solution for satisfying the requirements of the geographically dispersed service consumers who require fast response time Many cloud customers have specific restrictions about the legal boundaries in which their data or application can be hosted [Schubert et al. 2010]. Supplying resources in specific geographic locations to meet regulations in the places of those customers is an essential issue for a provider who wants to serve them Cloud computing providers should avoid the problem of the idle capacity (where their in-house hardware is not fully utilized all the time) and the problem of peaks in demand (where their own systems would be overloaded for a period). As the average demand of the system is several times smaller than the peak demand [Armbrust et al. 2010], providers are able to lease part of their resources to others, in order to avoid wasting their unused resources. this cooperation among cloud providers lowers the energy usage by promoting efficient utilization of the computing infrastructure	center. Current service providers handle this issue by overprovisioning data center capacity
	Process		
	Service	Adhering to published interface standards Developing a broker of services that can convert one product's interface into another product's interface "on the fly"	According to Chen and Doumeingts [2003], there are two distinguished approaches to obtain interoperability in practice: (1) Adhering to published interface standards (2) Developing a broker of services that can convert one product's interface into another product's interface "on the fly"
	Data	Data Portability	Users or applications that store data in the cloud, especially for SaaS and PaaS applications, often require access to the data so that it can be used by

			services of other cloud providers. Giving users control over their data is an important part of establishing trust and is paramount for creating interconnected cloud environments allowing users to easily move their data from one cloud to another. If a cloud provider stores data in their own proprietary format, then users cannot move their data to other vendors without considerable cost and technical effort. Therefore, industry standards and exporting tools, or at the very least formats that are publicly documented, are required to avoid data lock-in. Nowadays, data portability is hindered by the lack of proper technology and standards and non-portability of the applications and data, which is exploited by cloud service providers for their own benefits
Technological	Business		
	Process		
	Service		
	Data		
Organizational	Business	Provider-centric interoperability and client-centric interoperability	If cloud interoperability requires cloud providers to adopt and implement standard interfaces, protocols, formats, and architectural components that facilitate collaboration, we call that provider-centric interoperability. Provider-centric scenarios are categorized as hybrid and federated cloud scenarios. In client-centric interoperability, interoperability is not supported by cloud providers and cloud customers are required to initiate it by themselves or via third-party brokers. We consider multicloud and aggregated service by broker as client-centric interoperability scenarios
	Process	Standards developing organization (SDO), when they are technically involved in developing and publishing standards for cloud computing and cloud interoperability. Industrial or scientific consortia and standards-setting organization (SSO),bring organizations, companies, academia, and governmental institutes together to cooperate toward the purpose of wider adoption and development of cloud computing technologies	

	Service	SLA is a contract that describes a service and, most importantly, sets the expected service-level objectives (QoS expectations)	
	Data	Giving users control over their data (data liberation)	
Additional findings	General		

General information 6

Title of the article	Trust model to enhance security and interoperability of cloud environment. In IEEE international conference on cloud computing (pp. 69-79). Springer, Berlin, Heidelberg.
Author(s)	Li, W., & Ping, L.
Year of publication	2009

Relevance and review questions

Subject	**Answer (Yes/ No)**	**Argumentation**
Are the research objectives close to our own?	Yes	Yes
Is the context like our own?	Yes	Yes
Is this article used as a reference in other articles?	Yes	Yes
Does the article provide guidance for future research?	Yes	Yes
Does the article discuss about interoperability of business, process, services or data?	Yes	Data interoperability
Does the article discuss about factors enabling cloud interoperability?	Yes	Yes
Is the study sufficiently generic?	Yes	Yes
Is the study's methodology sufficient?	Yes	Yes

Extraction

Interoperability dimensions	Interoperability levels	Enabling factors	Main findings
conceptual	Business		
	Process		
	Service		
	Data	Trust model which ensures the security of cloud entities in cross-clouds applications	Trust model which ensures the security of cloud entities in cross-clouds applications
Technological	Business		
	Process		
	Service		
	Data	Code trust to make sure that user programs in cloud does not contain malicious code.	Distributed applications are often faced with two major security scenarios. First, user programs may contain malicious codes that may endanger or weaken resources. Second, resources once infected by network attacks may damage user applications. So Subject logic based trust model divides trust into several subclass: execution trust,code trust, authority trust, direct trust and recommendation trust.
Organizational	Business		
	Process		
	Service		
	Data		
Additional findings	General		

General information 7

Title of the article	What cloud interoperability connotates for EU policy making: Recurrence of old problems or new ones looming on the horizon?. Telecommunications Policy, 43(2), 154-170.

Author(s)	Ünver, M. B.
Year of publication	2019

Relevance and review questions

Subject	Answer (Yes/ No)	Argumentation
Are the research objectives close to our own?	Yes	
Is the context like our own?	Yes	
Is this article used as a reference in other articles?	Yes	
Does the article provide guidance for future research?	Yes	
Does the article discuss about interoperability of business, process, services or data?	Yes	Business interoperability
Does the article discuss about factors enabling cloud interoperability?	Yes	
Is the study sufficiently generic?	Yes	
Is the study's methodology sufficient?	Yes	

Extraction

Interoperability dimensions	Interoperability levels	Enabling factors	Main findings
conceptual	Business	Innovation and efficiency advantages Competition law tools Data portability	Distributed applications and service oriented architectures (SOA) also create innovation and efficiency advantages Lack of interoperability is an acquainted problem within the meaning of EU competition law particularly since Microsoft.This well-known case originated from Sun Microsystems's (Sun; ex-Oracle) claim that Microsoft, by refusing to disclose relevant interface information (a full set of specifications underlying interoperability between non- Microsoft work group server OSs and Windows client PC OSs), has infringed the Article 102 (formerly Article 82) TFEU. Sun contended that Microsoft had engaged in an abusive behaviour by reserving to himself the so-called information

			which Sun considered necessary to viably compete as a work group server OS supplier. Commission proposes a self-regulatory approach, encouraging providers to develop codes of conduct regarding the conditions, under which users can port data between cloud service providers (data portability)
	Process		
	Service		
	Data		
Technological	Business		
	Process		
	Service		
	Data		
Organizational	Business	Variety of organisations involved in this process range from all 'official' standard setting organisations (SSOs) to private standard development organisations (SDOs) to national government and international, including EU, initiatives to encourage the development of standards for cloud.	
	Process		
	Service		
	Data		
Additional findings	General		Standardisation is an important vehicle to ensure interoperability, bearing a significant potential for the creation of level playing field and new waves of innovation. Although there are already many standards defined for specific technologies used in cloud solutions, many of them are not widespread enough to reap the full benefit from the cloud computing. There are also efforts underway from leading standards organisations to clarify definitions, create common formats for improved interoperability

			and define specific contexts that vendors can adopt to improve compatibility and portability across a wide variety of cloud solutions While a proliferation of standards is not necessarily symptomatic of a problem for the cloud industry - being instead more a reflection of the variety and complex nature of the technologies that comprise the cloud ecosystem (Gleeson & Walden, 2014),vendor lock-in problem should be emphasized as this could accompany such fragmented market structures (Opara-Martins, Sahandi,& Tian, 2016).

General information 8

Title of the article	A survey on cloud interoperability: taxonomies, standards, and practice. ACM SIGMETRICS Performance Evaluation Review, 40(4), 13-22.
Author(s)	Zhang, Z., Wu, C., & Cheung, D. W.
Year of publication	2013

Relevance and review questions

Subject	**Answer (Yes/ No)**	**Argumentation**
Are the research objectives close to our own?	Yes	
Is the context like our own?	Yes	
Is this article used as a reference in other articles?	Yes	
Does the article provide guidance for future research?	Yes	
Does the article discuss about interoperability of business, process, services or data?	Yes	Business interoperability Process interoperability Service interoperability Data interoperability
Does the article discuss about factors enabling cloud interoperability?	Yes	
Is the study sufficiently generic?	Yes	
Is the study's methodology sufficient?	Yes	

Extraction

Interoperability dimensions	Interoperability levels	Enabling factors	Main findings
conceptual	Business		
	Process		
	Service		
	Data		
Technological	Business		
	Process		
	Service		
	Data	Security. Important security topics for cloud interoperability include authentication, authorization, accounting and encryption	
Organizational	Business	Many organizations are involved in various standardization efforts on the common theme of clouds.	Notable among them are the working groups operating under the Open Grid Forum (OGF) umbrella . Other prominent industry consortiums active in cloud standardization are Distributed Management Task Force Inc. (DMTF) and the Storage Networking Industry Association (SNIA).
	Process		
	Service	In terms of cloud interoperability, four important topics are involved on cloud SLA: architecture, template format, monitoring and SLA objectives	
	Data		
Additional findings	General		cloud users have increasing responsibilities for deploying over an SaaS cloud, to a PaaS cloud, and to an IaaS cloud, as well as more flexibility (portability); on the other hand, from IaaS to PaaS to SaaS, an increasing level of automation is achieved, since the users need to deal with less software deployment and management themselves. Cloud users would

			choose carefully among different cloud types depending on their own needs of portability and automation. For example, PaaS clouds offer faster setup for applications than IaaS clouds, and users can often exploit the free hosting opportunities provided by some PaaS providers (e.g. Google App Engine). When a user's application grows in scope and criticality, however, an IaaS cloud might be proven cheaper, more reliable and flexible, which leads to a transition across silos (from PaaS to IaaS)

General information 9

Title of the article	ETSI CLOUD–initial standardization requirements for cloud services. In *International Workshop on Grid Economics and Business Models* (pp. 105-115). Springer, Berlin, Heidelberg.
Author(s)	Oberle, K., & Fisher, M.
Year of publication	2010

Relevance and review questions

Subject	**Answer (Yes/ No)**	**Argumentation**
Are the research objectives close to our own?	Yes	
Is the context like our own?	Yes	
Is this article used as a reference in other articles?	Yes	
Does the article provide guidance for future research?	Yes	
Does the article discuss about interoperability of business, process, services or data?	Yes	Business interoperability Process interoperability Service interoperability Data interoperability
Does the article discuss about factors enabling cloud interoperability?	Yes	
Is the study sufficiently generic?	Yes	
Is the study's methodology sufficient?	Yes	

Extraction

Interoperability dimensions	Interoperability levels	Enabling factors	Main findings
conceptual	Business		
	Process	It should be possible to deploy components of a single application across multiple cloud infrastructure providers	Components of a single application could be deployed across multiple cloud infrastructure providers and possibly reconfigured while running, or with limited interruption, to respond to changes in usage patterns or resource availability, for example. Application configuration must be resilient to changes in the configuration within each cloud – for example scaling or migration of computational resources
	Service		
	Data		
Technological	Business	Market Platform represents a marketplace where various cloud computing services of different roles are offered. The main objective of the market platform is to bring customers and service providers together Aggregator - a large number of small and modular services arose, creating the opportunity to aggregate these services into value-added, complex solutions for certain needs.	The market platform represents a marketplace where various cloud computing services of different roles are offered. The main objective of the market platform is to bring customers and service providers together. The former can search for suitable cloud computing services while the latter can advertise its services. In addition to offering a platform for marketing and searching services, the market platform might also offer additional services to both service providers and customers, such as SLA contracting or billing With cloud computing a large number of small and modular services arose, creating the opportunity to aggregate these services into value-added, complex solutions for certain needs. This aggregation of services is accomplished by aggregators
	Process		
	Service		
	Data		
Organizational	Business		
	Process		

	Service		
	Data		
Additional findings	General		

Appendix E Data synthesis

Interoperability dimensions	Interoperability levels	Enabling factors	Main findings
conceptual	Business	Networked enterprises (e.g. the collaborative enterprise, digital enterprise, smart organization, extended enterprise, virtual enterprise. (Mezgár, I.,2020) Intra- and interorganizational value/supply chains(e.g. suppliers, business partners, employees, workers, customers) (Mezgár, I.,2020) Vendor lock-in avoidance (Kaur, K.,2017) Market: economic models driven optimization techniques; (e.g. market driven resource leasing) (Petcu, D.,2011) Utilizing multiple clouds at the same time is the only solution for satisfying the requirements of the geographically dispersed service consumers who require fast response time (Toosi, A. N.,2011) Supplying resources in specific geographic locations (e.g. to meet regulations) (Toosi, A. N.,2011)	Networked enterprises - Enterprise architectures of this kind are, e.g. the collaborative enterprise, digital enterprise, smart organization, extended enterprise, virtual enterprise. (Mezgár, I.,2020) High efficiency in intra- and interorganizational value/supply chains (Mezgár, I.,2020) Semantic interoperability and Seamless integration of entities within (intra) and outside (inter) the enterprises (e.g. suppliers, business partners, employees, workers, customers) (Mezgár, I.,2020) Vendor lock-in avoidance (Kaur, K.,2017) market: economic models driven optimization techniques; market driven resource leasing federation – application service providers host their services based on negotiated SLAs driven by competitive market prices; flexible mapping of services to resources to maximize efficiency, cost-effectiveness, and utilization; accounting; license flexibility. (Petcu, D.,2011)

		Growth in the scale of existing applications or surge in demand for a service (Toosi, A. N.,2011) Competition law tools (e.g. Lack of interoperability is an acquainted problem within the meaning of EU competition law) (Ünver, M. B.,2019)	Growth in the scale of existing applications or surge in demand for a service (Toosi, A. N.,2011) Avoiding Vendor Lock-In (Toosi, A. N.,2011) Utilizing multiple clouds at the same time is the only solution for satisfying the requirements of the geographically dispersed service consumers who require fast response time (Toosi, A. N.,2011) Many cloud customers have specific restrictions about the legal boundaries in which their data or application can be hosted [Schubert et al. 2010]. Supplying resources in specific geographic locations to meet regulations in the places of those customers isan essential issue for a provider who wants to serve them (Toosi, A. N.,2011) cloud computing providers should avoid the problem of the idle capacity (where their in-house hardware is not fully utilized all the time) and the problem of peaks in demand (where their own systems would be overloaded for a period). As the average demand of the system is several times smaller than the peak demand [Armbrust et al. 2010], providers are able to lease part of their resources to others, in order to avoid wasting their unused resources. this cooperation among cloud providers lowers the energy usage by promoting efficient utilization of the computing infrastructure (Toosi, A. N.,2011) Innovation and efficiency advantages (Ünver, M. B.,2019) Competition law tools. Lack of interoperability is an acquainted problem within the meaning of EU competition law (Ünver, M. B.,2019)

	Process	Alignment of cross organizational business process (Mezgár, I.,2020) Support distributed business processes, business-to-business integration. (Mezgár, I.,2020) Cloud standardization projects for the development of standards for clouds. (Kaur, K.,2017)	Alignment of cross organizational business process (Mezgár, I.,2020) support business process operations like distributed business processes, business-to-business integration. (Mezgár, I.,2020) Formulating standards for cloud computing is the most obvious solution for achieving interoperability and portability in Inter-clouds. A lot of efforts are devoted by cloud standardization projects for the development of standards for clouds covering the aspects concerned with development,deployment, security, management, storage, and so forth. (Kaur, K.,2017)
	Service	Model-driven approaches and semantic-based solutions. (Bouzerzour, N.E.H.,2020) Agents for the service description and discovery (Bouzerzour, N.E.H.,2020) Interface standards(Toosi, A. N.,2011) Service broker (Toosi, A. N.,2011)	Standardization, brokering, model-driven approaches and semantic-based solutions. (Bouzerzour, N.E.H.,2020) multiple agents for the service description and discovery (Bouzerzour, N.E.H.,2020) Adhering to published interface standards (Toosi, A. N.,2011) Developing a broker of services that can convert one product's interface into another product's interface "on the fly"(Toosi, A. N.,2011)
	Data	Information interoperability (Mezgár, I.,2020) platform-independent database abstraction layer (Bouzerzour, N.E.H.,2020) Data Portability (Toosi, A. N.,2011)	Information interoperability – to make query languages and different data models working together (Mezgár, I.,2020) platform-independent database abstraction layer (Bouzerzour, N.E.H.,2020)

		Trust model which ensures the security of cloud entities in cross-clouds applications (Li, W.,2009)	programming: move from one provider to another without dramatic reimplementation; common set of interfaces; standard API enabling an entity to build something once, then use it to monitor and control a variety of platforms; (Petcu, D.,2011) Data Portability (Toosi, A. N.,2011) Trust model which ensures the security of cloud entities in cross-clouds applications (Li, W.,2009) Data portability. EU commission proposes a self-regulatory approach, encouraging providers to develop codes of conduct regarding the conditions, under which users can port data between cloud service providers (Ünver, M. B.,2019)
Technological	Business	Market Platform (e.g. a marketplace where various cloud computing services of different roles are offered) The main objective of the market platform is to bring customers and service providers together (Oberle, K.,2010) Aggregator - a large number of small and modular services creating the opportunity to aggregate these services into value-added, complex solutions for certain needs. (Oberle, K.,2010)	Market Platform represents a marketplace where various cloud computing services of different roles are offered. The main objective of the market platform is to bring customers and service providers together (Oberle, K.,2010) Aggregator - a large number of small and modular services arose, creating the opportunity to aggregate these services into value-added, complex solutions for certain needs. (Oberle, K.,2010)
	Process	Model-driven engineering (MDE) cloud modeling framework (CloudMF),and cloud modeling language (CloudML) (Bouzerzour, N.E.H.,2020) Microservices - An application development approach, in which an application is developed as a group of small modular services that	Model-driven engineering (MDE) cloud modeling framework (CloudMF),and cloud modeling language (CloudML) (Bouzerzour, N.E.H.,2020) Microservices - An application development approach, in which an application is developed as a group of small modular services that communicated with each other (Bouzerzour, N.E.H.,2020)

		communicated with each other (Bouzerzour, N.E.H.,2020)	
	Service	Middleware (Bouzerzour, N.E.H.,2020) Service Oriented Architecture (Bouzerzour, N.E.H.,2020) Service description languages (Bouzerzour, N.E.H.,2020) Open libraries and Open services which rely on the use of abstraction layers and adapters (Kaur, K.,2017)	Middleware intermediate the communication between distributed applications (Bouzerzour, N.E.H.,2020) SOA A set of services that are provided at a network address and that are published, discovered and invoked over the web. (Bouzerzour, N.E.H.,2020) Service description languages A language that enables the description of services functionalities, properties (Bouzerzour, N.E.H.,2020) Open libraries and Open services which rely on the use of abstraction layers and adapters (Kaur, K.,2017)
	Data	Semantic technologies that facilitate the exchange and interpretation of data between services(Bouzerzour, N.E.H.,2020) Standardized APIs and data models are the two solutions for achieving semantic interoperability (Kaur, K.,2017) Cloud Data Management Interface (CDMI) - storage backbone in cloud interoperability, (Kaur, K.,2017) Security (Zhang, Z.,2013)	Semantic technologies facilitate the exchange and interpretation of data between services(Bouzerzour, N.E.H.,2020) Common data models - A standard format to which heterogeneous data is transformed and that allows the data comparison(Bouzerzour, N.E.H.,2020) Standardized APIs and data models are the two solutions which are usually suggested for achieving semantic interoperability (Kaur, K.,2017) Considered as the storage backbone in cloud interoperability, CDMI defines the final interface which can be used by application to carry out CRUD operations in the cloud (Kaur, K.,2017) Code trust to make sure that user programs in cloud does not contain malicious code. (Li, W.,2009)

			Security. Important security topics for cloud interoperability include authentication, authorization, accounting and encryption (Zhang, Z.,2013)
Organizational	Business	Provider-centric interoperability and client-centric interoperability (Toosi, A. N.,2011)	Provider-centric interoperability and client-centric interoperability (Toosi, A. N.,2011)
	Process	Various Cloud Computing Standardization Organizations (Kaur, K.,2017)	Various Cloud Computing Standardization Organizations (Kaur, K.,2017) Standards developing organization (SDO), when they are technically involved in developing and publishing standards for cloud computing and cloud interoperability. Industrial or scientific consortia and standards-setting organization (SSO),bring organizations, companies, academia, and governmental institutes together to cooperate toward the purpose of wider adoption and development of cloud computing technologies (Toosi, A. N.,2011) Variety of organisations involved in this process range from all 'official' standard setting organisations (SSOs) to private standard development organisations (SDOs) to national government and international, including EU, initiatives to encourage the development of standards for cloud. (Ünver, M. B.,2019) Many organizations are involved in various standardization efforts on the common theme of clouds. (Zhang, Z.,2013)
	Service	SLA is a contract that describes a service and, most importantly, sets the expected service-level objectives (QoS expectations) (Toosi, A. N.,2011)	SLA is a contract that describes a service and, most importantly, sets the expected service-level objectives (QoS expectations) (Toosi, A. N.,2011) In terms of cloud interoperability, four important topics are involved on cloud SLA: architecture, template format, monitoring and SLA objectives(Zhang, Z.,2013)

	Data	Data liberation (Giving user community control over their data)(Toosi, A. N.,2011)	Giving users control over their data (data liberation) (Toosi, A. N.,2011)
Additional findings	General		• Intramodel interoperability is highly addressed because the interoperability between services of the same delivery model (eg, SaaS-SaaS, IaaS-IaaS) is essential for an efficient service delivery over the cloud. This interoperability provides more instances for the data processing. Consequently, it decreases the load on each computation instance by distributing the initial load on several nodes. This enables the cloud to handle the traffic effectively and it reduces the downtime. However, intramodel interoperability is also a drawback because it does not guarantee interoperability with other delivery models. • Intermodel interoperability, in the other hand, enables interoperability between services of different delivery models (eg, PaaS-IaaS, SaaS-PaaS), which gives the clients a range of choices over which platform and infrastructure to run or deploy their applications on. Besides, when services require more resources (eg, CPU, RAM) the intermodel interoperability will enable vertical scaling to acquire more capacity. • Organizations are reluctant to adopt cloud solutions because they may be unable to make heterogeneous smanagement and planning applications (eg, CRM, ERP) interoperate due to the lack of SaaS interoperability solutions. • Cloud providers are the main cause for the lack of interoperable SaaS solutions because they focus on the added-value of their software. Therefore, they offer customized services compared with competitors' services. The lack of standardization may unwillingly lock-in clients to one provider, even though better services (in regards to QoS and cost) may exist, which prevents the fair competition in the cloud market.

			•Standards should be created with flexibility and extensibility in mind, taking into account that cloud computing evolves at a very fast pace

Appendix F Results and conclusions of literature search

Details of the results of literature search is elaborated below

The interoperability of business

Avoidance of vendor lock-in is mentioned as one of the main enabling factors from a business perspective to support cloud interoperability(Kaur et al., 2017; Toosi et al., 2014; Ünver, 2019) . Petcu (Petcu & Vasilakos, 2014) mentions *Business strategies and Economic model driven optimization* mechanisms as minimal requirements of interoperability at Business level for Consuming Resources and Services from Multiple Clouds. According to Mezgár (Mezgár & Rauschecker, 2014), basic characteristics of cloud computing look very promising for the networked enterprises. Interoperability in cloud computing has a basic role in setting up *Enterprise architectures of networked enterprises* (e.g. collaborative enterprise, digital enterprise, smart organization, extended enterprise, virtual enterprise etc). Mezgár(Mezgár & Rauschecker, 2014) further points out that cloud interoperability can result in *high efficiency in intra- and interorganizational value/supply chains* (e.g. suppliers, business partners, employees, workers, customers). Utilizing multiple clouds at the same time is the only solution for satisfying the requirements of the *geographically dispersed service consumers* who require fast response time (Toosi et al., 2014). Many cloud customers have specific restrictions about the legal boundaries in which their data or application can be hosted. Supplying resources in specific geographic locations to *meet regulations* in the places of those customers is an essential issue for a provider who wants to serve them(Toosi et al., 2014). *Scalability* also acts as an enabler for cloud interoperability by supporting the growth in the scale of existing applications or surge in demand for a service(Toosi et al., 2014). Cloud computing providers should *avoid the problem of the idle capacity* (where their in-house hardware is not fully utilized all the time) and the problem of peaks in demand (where their own systems would be overloaded for a period). As the average demand of the system is several times smaller than the peak demand, providers are able to lease part of their resources to others, in order to avoid wasting their unused resources. This cooperation among cloud providers *lowers the energy usage by promoting efficient utilization* of the computing infrastructure(Toosi et al., 2014) and acts as an enabler for cloud interoperability. Innovation and efficiency advantages also acts as an enabler for cloud interoperability(Ünver, 2019). Lack of interoperability is an acquainted problem within the meaning of EU competition law(Ünver, 2019) . Any behaviour on the part of a dominant cloud provider that contains an exclusionary element (e.g., refusal to deal,exclusive dealing, tying) might be construed as violating EU competition law insofar as this is found to likely result in a market foreclosure.So enforcing *competition law* also acts as an enabler for interoperability from business perspective. From a technical perspective, *Market Platform* (e.g. a marketplace where various cloud computing services of different roles are offered) is an enabler for cloud interoperability(Oberle & Fisher, 2010). *Aggregator* - a large number of small and modular services creating the opportunity to aggregate these services into value-added, complex solutions for certain needs – also supports interoperability of business in cloud platforms(Oberle & Fisher, 2010). From an organizational point of view, two different approaches enabling cloud interoperability are *Provider-centric interoperability* and *client-centric interoperability* (Toosi et al., 2014). In client-centric interoperability, cloud customers are required to initiate interoperability by themselves or via third-party brokers. When cloud providers adopt and implement standard interfaces, protocols, formats, and architectural components that facilitate collaboration, it is called provider-centric interoperability.

The interoperability of processes

Alignment of cross organizational business process(Mezgár & Rauschecker, 2014) is an important factor in enabling cloud interoperability. *Distributed business processes and business-to-business integration*(Mezgár & Rauschecker, 2014)also act as an enabling factor for interoperability of processes from a cloud platform perspective. *Cloud standardization projects* for the development of standards for clouds(Kaur et al., 2017) is also an important enabler for the interoperability of processes. On a technological layer, *Model-driven engineering (MDE),cloud modeling framework (CloudMF),and cloud modeling language (CloudML)*(Bouzerzour et al., 2020) can enable interoperability of processes. *Microservices* - an application development approach, in which an application is developed as a group of small modular services that communicate with each other (Bouzerzour et al., 2020) – supports interoperability of processes in cloud platform environments. Various *Cloud Computing Standardization Organizations* (Kaur et al., 2017) are working on standardizing the interoperability of processes in cloud platforms. Industrial or scientific consortia and *standards-setting organization* (SSO),bring organizations, companies, academia, and governmental institutes together to cooperate toward the purpose of wider adoption and development of cloud computing technologies(Toosi et al., 2014).Variety of organisations involved in this process range from all 'official' standard setting organisations (SSOs) to private standard development organisations (SDOs) to national government and international, including EU, initiatives to encourage the *development of standards for cloud*.(Ünver, 2019)

The interoperability of services

Many research and academic studies addressed the service interoperability and the vendor lock-in problem in both single and interconnected clouds environments. The researchers proposed solutions such as *standardization, brokering, model-driven approaches and semantic-based solutions*. *Agents for the service description and discovery* can also enable transparent interoperability between incompatible public PaaS services.(Bouzerzour et al., 2020). Adhering to *published interface standards* and developing a *broker of services* that can convert one product's interface into another product's interface "on the fly" are two distinguished approaches to obtain interoperability according to Chen(Chen & Doumeingts, 2003). *Middleware* intermediate the communication between distributed applications and can enable service interoperability on technological layer. *Service description languages* enable the description of services functionalities and properties, which can support in interoperability. *Open libraries* and open services rely on the use of abstraction layers and adapters. These basically support interoperability of multiple independent clouds(Kaur et al., 2017).Cloud providers define (or negotiate with customers) a *service-level agreement (SLA)* to specify what they guarantee. From an organizational perspective, SLA is a contract that describes a service and, most importantly, sets the expected service-level objectives (QoS expectations). It can even encompass more details such as penalties applied to the provider if it does not deliver services according to the service level objectives(Toosi et al., 2014). Service Level Agreement (SLA) is identified as the only way that the accountability and auditability of a CSP is clarified(Cayirci, Garaga, De Oliveira, & Roudier, 2016) and can ensure compliance in the interoperability between cloud services.

The interoperability of data

Information interoperability which makes query languages and different data models work together enables interoperability of data in cloud ecosystems(Mezgár & Rauschecker, 2014).*Platform-independent database abstraction layer* can support data portability and interoperability between different cloud-based data storage services(Bouzerzour et al., 2020). *Trust model which ensures the*

security of cloud entities in cross-clouds applications ensures the interoperability of data among the cloud platforms in a secure manner(Li & Ping, 2009).*Standardized APIs and data models* are the two solutions for achieving semantic interoperability(Kaur et al., 2017) from a technological perspective. Semantic technologies that facilitate the exchange and interpretation of data between services(Bouzerzour et al., 2020) enable data interoperability. *Cloud Data Management Interface (CDMI)*, considered as the storage backbone in cloud interoperability, defines the final interface which can be used by application to carry out CRUD operations on data in the cloud(Kaur et al., 2017). Code trust, to make sure that user programs in cloud does not contain malicious code (Li & Ping, 2009) is important for security of data in cloud platform interoperability. Other important security topics for cloud interoperability include authentication, authorization, accounting and encryption(Zhang et al., 2013). From an organization perspective, *Data liberation* aids data interoperability. Data liberation gives users control over their data and is a a step toward providing freedom of data movement between clouds. Security and privacy management that is compliant with government laws(Gracia-Tinedo et al., 2018), Security policies(Gracia-Tinedo et al., 2018) and *Trust relationships among participants*(Hamad Witti, 2018) are necessary for ensuring data security during information exchange between cloud platforms.Data Stewardship in cloud(Labrador, Mościcki, Lamanna, & Pace, 2015) is needed to improve governance in multi-cloud platforms.

General findings

Organizations are reluctant to adopt cloud solutions because they may be unable to make heterogeneous management and planning applications (eg, CRM, ERP) interoperate due to the lack of SaaS interoperability solutions. Cloud providers are the main cause for the lack of interoperable SaaS solutions because they *focus on the added-value of their software*. Therefore, they offer customized services compared to competitors' services. The lack of standardization may unwillingly lock-in clients to one provider, even though better services (in regards to QoS and cost) may exist, which prevents the fair competition in the cloud market(Bouzerzour et al., 2020). *Standards should be created with flexibility and extensibility in mind*, taking into account that cloud computing evolves at a very fast pace(Kaur et al., 2017).

Appendix G Interview protocol

Introduction:

The interview will start with a general introduction to explain the goal of the interview and the research objective. After this, both interviewer and interviewee will briefly introduce themselves. The previously agreed right to confidentiality and anonymity will be reiterated by stating that nothing said by the participant would be attributed to him/her without first seeking and obtaining permission. Participant's right not to answer any question will also be emphasised and that the interview would be stopped if the participant wished.

Opening questions:

The researchers wish to establish that the interviewees are a sufficient intersection of the organization.

General information

1. Which company are you working for?
2. Which function do you have within this company?
3. What is your highest, completed, education?
4. How many years of experience do you have within this company?
5. How many years of experience do you have in your current field?
6. What would be the role of the company you represent in a Platform Ecosystem?

First Part:

The purpose of these questions is to openly ask and discuss various factors enabling the interoperability of cloud platform ecosystem in enterprises, without discussing any of the listed themes for the interview. These questions will also help to get an understanding of the familiarity of the interviewees with the subject with an open discussion

7. How would you define Interoperability of cloud platform ecosystems?
8. To what extent do you consider yourself familiar with interoperability of cloud platform ecosystems?
9. Have you ever been involved in any stage of implementation of applications/solutions which are Interoperable between different cloud platform ecosystems? If so, please elaborate your experience.
10. Based on your knowledge and experience, what are the main enabling factors for interoperability of cloud platform ecosystems? Please elaborate, and based on your experience give an example.

Second part:

The purpose of the questions in this part is to validate and refine our initial framework. We wish to discuss this framework and get an in-depth understanding to what extent you consider the elements in this framework to be relevant for your organization/ in your line of work. We would like an emphasis on the levels relevant in your line of work. (a copy of our framework will be presented for this part)

11. Which interoperability dimension mentioned in the framework are you more familiar with – conceptual layer, technical layer and/or organizational layer?

12. Which interoperability level(s) in our framework are relevant in your line of work – Business, process, service, data?
13. To what extent do you consider the below enabling factors in our framework as relevant for business interoperability on a conceptual level ,for your organization? Please elaborate on your answer, explain why you think is it relevant and based on your experience give an example.

- Vendor lock-in avoidance
- Scalability
- Regulations
- Inter-organizational supply chain in networked enterprises

14. To what extent do you consider the below enabling factors in our framework as relevant for process interoperability on a conceptual level,for your organization? Please elaborate on your answer, explain why you think is it relevant and based on your experience give an example.

- Alignment of cross organizational business process
- Supporting distributed business process

15. To what extent do you consider the below enabling factors in our framework as relevant for service interoperability on a conceptual level, for your organization? Please elaborate on your answer, explain why you think is it relevant and based on your experience give an example.

- Model-driven approach
- Cloud standardization projects
- Service oriented architecture

16. To what extent do you consider the below enabling factors in our framework as relevant for data interoperability on a conceptual level, for your organization? Please elaborate on your answer, explain why you think is it relevant and based on your experience give an example.

- Information interoperability
- platform-independent database abstraction layer
- Data Portability
- Trust model in cross-clouds applications

17. To what extent do you consider the below enabling factors in our framework as relevant for business interoperability on a technical level,for your organization? Please elaborate on your answer, explain why you think is it relevant and based on your experience give an example.

- Market Platform
- Aggregator

18. To what extent do you consider the below enabling factors in our framework as relevant for process interoperability on a technical level,for your organization? Please elaborate on your answer, explain why you think is it relevant and based on your experience give an example.

- Cloud modelling framework and cloud modelling languages

- Microservices

19. To what extent do you consider the below enabling factors in our framework as relevant for service interoperability on a technical level,for your organization? Please elaborate on your answer, explain why you think is it relevant and based on your experience give an example.
- Middleware
- Service broker
- Service description languages
- Agents for the service description and discovery
- Open libraries

20. To what extent do you consider the below enabling factors in our framework as relevant for data interoperability on a technical level,for your organization? Please elaborate on your answer, explain why you think is it relevant and based on your experience give an example.
- Semantic technologies
- Standardized APIs and data models
- Cloud Data Management Interface (CDMI)
- Security

21. To what extent do you consider the below enabling factors in our framework as relevant for business interoperability on an organizational level,for your organization? Please elaborate on your answer, explain why you think is it relevant and based on your experience give an example.
- Provider-centric interoperability and client-centric interoperability

22. To what extent do you consider the below enabling factors in our framework as relevant for process interoperability on an organizational level,for your organization? Please elaborate on your answer, explain why you think is it relevant and based on your experience give an example.
- Cloud Computing Standardization Organizations

23. To what extent do you consider the below enabling factors in our framework as relevant for service interoperability on an organizational level, for your organization? Please elaborate on your answer, explain why you think is it relevant and based on your experience give an example.
- Service Level agreement

24. To what extent do you consider the below enabling factors in our framework as relevant for data interoperability on an organizational level, for your organization? Please elaborate on your answer, explain why you think is it relevant and based on your experience give an example.
- Data liberation

25. Based on your experience, please rate the enabling factors according to their relevance and importance. (You can pick top 5 or top 10 factors and rate them). Please also give a brief explanation on why you have given this rating.

Third part:

The purpose of these questions is to get an understanding of the overall impression of our framework and to give an opportunity to point out missing elements in the framework and elements within.

26. What is your overall impression on the framework and various elements discussed? Please elaborate.
27. To what extend do you consider the framework to be useful for implementing interoperable cloud platform ecosystems in your organization? Please elaborate.
28. Are there any missing elements we need to consider adding to our framework?

Appendix H Information email and consent

To: <Respondent >
From: Jaimon Kanichai
Date: <date>
Subject: Participation in my thesis research on Cloud Interoperability

Hi <Respondent >,

To complete my Masters in Business Process Management and IT, I am doing research on "Enabling factors towards the successful interoperability of cloud platform ecosystems in enterprises". As discussed briefly with you, I would like to conduct interviews as part of the empirical study of my research. I am sending this email based on your verbal confirmation regarding the willingness to participate in the interview.

For the interview, I will share brief background information about the interview topic with you, as an attachment to this email. There are a couple of questions in the attached word document. Please provide your response to those questions either via reply email or during the interview meeting.

The interview is a semi-structured interview, based on a framework which I will present during the interview. I am scheduling one-hour meeting for the interview. I will follow-up after the interview for validating the interview transcript and to clarify any outstanding questions if there are any. I expect an addition 30 minutes of your time for this activity.

I will send the meeting invite for week 14. Please feel free to reschedule to a time suitable for you. I will be available in <organization> office for a face to face meeting and will book a meeting room. If you are not available on any day on week 14 or 15 in <organization> office, we can have MS Teams meeting.

Please find below standard declaration for your consent for the interview. By accepting the meeting invite you are officially giving your consent to this declaration.
"I declare that the interview is voluntary and that I am entitled to end the interview at any point. I give my consent for the audio of the interview to be recorded, knowing that this audio recording will be deleted once the interview has been correctly transcribed. I give my consent for the use of the data gathered during this interview in the analysis of the research, knowing that it will be anonymized."

Thank you in advance for your time.

Best regards
Jaimon

Open Universiteit
www.ou.nl

Email attachment

Brief background information about the interview topic :

In recent years, companies leverage cloud computing technologies that allow third-party developers to implement complementary applications and customers to quickly deploy these applications forming a cloud platform ecosystem. Although there were a plethora of services deployed in the cloud, single cloud services often failed to answer the clients' evolving and complex requirements, and resulted in stronger need for multiple cloud applications to be able to work seamlessly together. However most new cloud providers propose their own solutions and proprietary interfaces for access to resources and services. This heterogeneity is a crucial problem as it raises barriers to the path of the ubiquitous cloud realization. Cloud interoperability represents the ability of heterogeneous systems, which are deployed in the same cloud or in multiple clouds, to communicate together.Interoperability of cloud applications has a huge impact on the cloud adoption in organizations. This study aims to identify the factors which enable successful interoperability of cloud platform ecosystems in enterprises, on various interoperability levels such as technical interoperability, business level interoperability and organizational level interoperability. This research proposes a framework of "enabling factors" to benefit enterprises which leverage the multi-cloud platforms for realizing business requirements, by studying interrelationships between people, process, data and services with cloud interoperability and cloud computing ecosystem.

Please provide your response to below questions :

1. How would you define Interoperability of cloud platform ecosystems?
2. To what extent do you consider yourself familiar with interoperability of cloud platform ecosystems?Have you ever been involved in any stage of implementation of applications/solutions which are Interoperable between different cloud platform ecosystems?
3. Based on your knowledge and experience, what are the main enabling factors for interoperability of cloud platform ecosystems?

Appendix I Participant overview

Role of the company respondent represents in Platform Ecosystem	Function	Education	Years of experience in company	Years of experience in this field	Familiarity with topic "interoperability of cloud platform ecosystems"	How would you define Interoperability of cloud platform ecosystems? Main enabling factors for interoperability according to respondent.
Consumer	Enterprise Architect	University	4	14	"I have been part of multiple cloud provider selections and implementations. Also involved in migration of servers from datacenter on-premise to datacenter cloud."	Cloud interoperability basically means when an application is switched from one cloud provider to another cloud provider, it should work seamlessly. Main enabling factor for interoperable solutions (cloud or non cloud), is to follow open standards in design and development of applications
Consumer	Integration specialist	University	6	15	"Experienced in integrating cloud platform applications with on-premise system"	Cloud interoperability refers to the ability of the systems to collaborate effectively across different cloud platforms. Main enabling factor is communication between application components using APIs and metadata. From business perspective, the main enabling factor is business flexibility.

Autonomous complementors - Cloud Platform Ecosystem 2	Senior consultant / Team lead	University	1	8	"Technical lead in designing and developing applications in cloud platforms. IT architect for application development in cloud platforms."	Cloud interoperability is the ability of applications to exchange information and interact with cloud services from multiple cloud platforms. Main enabling factor is the business demands . For example, modular based IT architectures which provides agility to business need interoperable cloud applications.
Autonomous complementors - Cloud Platform Ecosystem 2	Application developer	Bachelors	2	2	"Application development in PaaS"	Interoperability is the ability to migrate code from one environment to another without modification. Main enabling factor is digital transformation of organization. Moving towards cloud native applications and use of multi-cloud services.
Autonomous complementors - Cloud Platform Ecosystem 1	Application developer	Bachelors (technical)	4	4	"Developed applications for multiple technologies for various cloud development platforms"	Cloud application interoperability means cloud services can understand each other's APIs, configuration, authorization. Cloud Platform Interoperability means the ability to move applications and data between different platform providers. Main enabling factor is business requirements for additional functionalities. From a technical perspective cloud interoperability is facilitated by having interface standards between various PaaS providers
Consumer	Chief Information Security Officer	University	2	16	"Overall responsible for IT security. Managed cloud migration projects and cloud integration with on-premise systems"	Cloud interoperability can leverage services from various cloud vendors. This is very important for organization to maintain its competitive edge.

Autonomous complementors - Cloud Platform Ecosystem 1	Director – Business Consulting	Business economist (Diploma)	6	22	"Implemented cloud strategy for multiple clients in several roles such as liaison between business and IT, techno functional lead, consulting partner etc"	Cloud interoperability means each cloud vendor in multicloud infrastructure is compatible with each other and a consumer can benefit from each provider's services. Organizations need to avoid information silos and fragmented processes while moving into the cloud. This is the main enabler for cloud interoperability. Some organizations follow cloud first strategy. Cloud interoperability is essential for these organizations to have a single source of truth, accurate data.
Consumer	Group Leader – Digital Platforms	HBO (Technische Informatica)	6	16	"As group leader for Digital Process Excellence program, I have been driving digital transformation strategy including cloud adoption and customer collaboration."	Interoperability in the context of cloud environments, is the ability of applications to work with multiple cloud platforms and facilitate the exchange of information and data across them. Main enabling factor is cost-benefit analysis to migrate on-premises datacenters to cloud. Another enabling factor is innovation – for example cloud analytical applications, customer collaboration in cloud etc

Appendix J Interview Transcripts

Interview number :	int_C1
Which function do you have within this company?	Enterprise Architect (TP)
What is your highest, completed, education?	University
How many years of experience do you have within this company?	4
How many years of experience do you have in your current field?	14
What would be the role of the company you represent in a Platform Ecosystem?	Client (Consumer)
To what extent do you consider yourself familiar with interoperability of cloud platform ecosystems?	I have been part of vendor selection of multiple cloud providers and implementations. Also involved in migration of servers from datacenter on-premise to datacenter cloud.
How would you define Interoperability of cloud platform ecosystems? Based on your knowledge and experience, what are the main enabling factors for interoperability of cloud platform ecosystems?	Cloud interoperability basically means when an application is switched from one cloud provider to another cloud provider, it should work seamlessly. Main enabling factor for interoperable solutions (cloud or non cloud), is to follow open standards in design and development of applications.

Interoperability dimensions	Interoperability levels	Enabling factors	Interview transcript	Closed coding	Rationale for coding
conceptual	Business	Vendor lock-in avoidance	Depends on SaaS or PaaS or IaaS. For SaaS, no easy viable solution. Even if you have another vendor, the migration is long and heavy process. The more sophisticated and specialised tool you need, you have less options to avoid lock-in For IaaS layer, for computing power and storage space - then yes	Agree	Respondent mentions that vendor lock-in avoidance can be an enabling factor for IaaS and PaaS layer. Respondent is not convinced that it is possible to avoid vendor

					lock-in in the SaaS layer.
		Scalability	Moving to IaaS to avoid cost. Less lead time for IaaS	Strongly agree	Respondent agrees with "enabling factor" and can substantiate it based on his/her experience
		Regulations	Regulations are impacting everybody. Not as important for interoperability. It is helping but not an enabling factor	Disagree	Respondent disagrees with "enabling factor" and can provide reasoning
		Inter-organizational supply chain in networked enterprises	There is no strict need to have specifically designed business process to have cloud solutions.It is otherway around. Cloud can support busines process. Cloud can provide fexibility in business process. Can help in organic growth rather than in a revolution.	Disagree	Respondent disagrees with "enabling factor" and can provide reasoning
	Process	Alignment of cross organizational business process	There is no strict need to have specifically designed business process to have cloud solutions.It is otherway around. Cloud can support busines process. Cloud can provide fexibility in business process. Can help in organic growth rather than in a revolution.	Disagree	Respondent disagrees with "enabling factor" and can provide reasoning

		Supporting distributed business process	There is no strict need to have specifically designed business process to have cloud solutions.It is otherway around. Cloud can support busines process. Cloud can provide fexibility in business process. Can help in organic growth rather than in a revolution.	Disagree	Respondent disagrees with "enabling factor" and can provide reasoning
	Service	Model-driven approach		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
		Cloud standardization projects		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
		Service oriented architecture	Quite difficult to answer. SoA can increase complexity. Interoperability can be result of synergy. But at the expense of complexity and security.	Agree	Respondent agrees with "enabling factor" and can provide reasoning
	Data	Information interoperability	Business semantics are important. It is not a big factor for interoperability currently but may be in future.	Disagree	Respondent disagrees with "enabling factor" and can provide reasoning
		Platform-independent database abstraction layer		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
		Data Portability	Not necessarily. You can have intermediary which can do the translation for you.	Disagree	Respondent disagrees with "enabling factor" and can provide reasoning

		Trust model in cross-clouds applications	The more secure the better. One of the core things for interoperable solution. If you cannot trust other party, you cannot have interoperable solution	Strongly agree	Respondent agrees with "enabling factor" and can substantiate it based on his/her experience
Technological	Business	Market Platform	For smaller companies which do not have capabilities in-house. Enables to use more and more cloud application from market place. These services are usually interoperable. Downside is vendor lock-in	Strongly agree	Respondent agrees with "enabling factor" and can substantiate it based on his/her experience
		Aggregator		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
	Process	Cloud modelling framework and cloud modelling languages		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
		Microservices	Sames as that of SoA. It can provide interoperability at the expense of complexity and security.	Agree	Respondent agrees with "enabling factor" and can provide reasoning
	Service	Middleware	It is used quite heavily	Strongly agree	Respondent agrees with "enabling factor" and can substantiate it

					based on his/her experience
		Service broker		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
		Service description languages		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
		Agents for the service description and discovery		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
		Open libraries	For developers, it is very important	Agree	Respondent agrees with "enabling factor" and can provide reasoning
	Data	Semantic technologies		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
		Standardized APIs and data models		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
		Cloud Data Management Interface(CDMI)	Yes for sure. This helps cloud administrators to administer multiple clouds from same console. So this is supporting interoperability from an admin perspective.	Agree	Respondent agrees with "enabling factor" and can provide reasoning

		Security	Strong encryption, Authentication, Authorization are needed for securely transferring data across cloud platforms	Strongly agree	Respondent agrees with "enabling factor" and can substantiate it based on his/her experience
Organizational	Business	Provider-centric interoperability and client-centric interoperability	Depends on the application because you might want the provider to be responsible for critical ones. Mission critical should be provider centric. For more control, client centric is more important.	Agree	Respondent agrees with "enabling factor" and can provide reasoning
	Process	Cloud Computing standardization Organizations	Good to have some organization setting up standards. I am not familiar. Big companies may not like restrictions imposed by standards organization. Smaller players might adhere to standards and market themselves as "standards compliant" solution.	Agree	Respondent agrees with "enabling factor" and can provide reasoning
	Service	Service Level agreement	Extremely important. One of the things to be reviewed first.	Strongly agree	Respondent agrees with "enabling factor" and can substantiate it based on his/her experience
	Data	Data liberation	One thing about data is format. You may be able to export but if you do not know metadata, you will not be able to use it. Proper documentation and following standards is very important.	Agree	Respondent agrees with "enabling factor" and can provide reasoning

Additional comments	Framework covers a lot of areas of enterprise interoperability. This can be a good starting point for a practical framework for cloud interoperability. Licensing model is one of the aspect which seems to be missing in the framework.

Interview number :	int_C2
Which function do you have within this company?	Integration specialist (MHK)
What is your highest, completed, education?	University
How many years of experience do you have within this company?	6
How many years of experience do you have in your current field?	15
What would be the role of the company you represent in a Platform Ecosystem?	Consumer
To what extent do you consider yourself familiar with interoperability of cloud platform ecosystems?	Experienced in integrating cloud platform applications with on-premise system
How would you define Interoperability of cloud platform ecosystems? Based on your knowledge and experience, what are the main enabling factors for interoperability of cloud platform ecosystems?	Cloud interoperability refers to the ability of the systems to collaborate effectively across different cloud platforms. Main enabling factor is communication between application components using APIs and metadata. From business perspective, the main enabling factor is business flexibility.

Interoperability dimensions	Interoperability levels	Enabling factors	Interview transcript	Closed coding	Rationale for coding
conceptual	Business	Vendor lock-in avoidance	Locked-in to one provider is a form of monopoly for the vendor. It should be possible to interoperate with other vendors.	Agree	Respondent agrees with "enabling factor" and can provide reasoning

		Scalability	When the application is interoperable, resources can be added on the infrastructure layer on the fly and scale as rapidly as the customers require.	Agree	Respondent agrees with "enabling factor" and can provide reasoning
		Regulations	Every vendor should be compliant. Every continent has some regulations.	Neither agree nor disagree	Respondent mentions that regulations are important but is unable to provide a proper justification regarding why it is an “enabling factor”
		Inter-organizational supply chain in networked enterprises	Yes it promotes cloud interoperability. Interoperable cloud allows suppliers and buyers to connect and do business on a single platform	Agree	Respondent agrees with "enabling factor" and can provide reasoning
	Process	Alignment of cross organizational business process	Business process modelling and interoperable cloud solutions should go hand in hand. There should be a feasibiity study.	Agree	Respondent agrees with "enabling factor" and can provide reasoning
		Supporting distributed business process	Business process modelling and interoperable cloud solutions should go hand in hand. There should be a feasibiity study.	Agree	Respondent agrees with "enabling factor" and can provide reasoning
	Service	Model-driven approach	We have seen in previous developmental architecture. MDA is not cloud specific approach. It is a software	Strongly agree	Respondent agrees with

			design approach. It is suitable for cloud native applications also.		"enabling factor" and can substantiate it based on his/her experience
		Cloud standardization projects		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
		Service oriented architecture	API mapping is important. General enterprise architect principle. Cloud is just an extension.	Strongly agree	Respondent agrees with "enabling factor" and can substantiate it based on his/her experience.
	Data	Information interoperability	Should be some standard mechanism for interoperability. Mapping tables can be used for this.	Agree	Respondent agrees with "enabling factor" and can substantiate it based on his/her experience
		Platform-independent database abstraction layer	DB layer is independent of application layer. Can avoid lock-in with one database	Agree	Respondent agrees with "enabling factor" and can provide reasoning
		Data Portability		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"

		Trust model in cross-clouds applications	Required for SSO	Agree	Respondent agrees with "enabling factor" and can provide reasoning
Technological	Business	Market Platform	Key principle for integration. One development platform, you can subscribe for multiple applications	Agree	Respondent agrees with "enabling factor" and can provide reasoning
		Aggregator		Neither agree nor disagree	
	Process	Cloud modelling framework and cloud modelling languages	Reduce development time and time to market. To make standardization of development, interoperating party only needs to know only your header details. Minimum impact when there is a change.	Strongly agree	Respondent agrees with "enabling factor" and can substantiate it based on his/her experience
		Microservices		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
	Service	Middleware	Important component for understanding sender structure and converting to receiver structure (like adapter). Just map it.	Agree	Respondent agrees with "enabling factor" and can provide reasoning
		Service broker		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"

		Service description languages		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
		Agents for the service description and discovery		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
		Open libraries	open structure - helps in interoperability	Agree	Respondent agrees with "enabling factor" and can provide reasoning
	Data	Semantic technologies		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
		Standardized APIs and data models	Explore standard APIs by providing test data or input and checking the HTTP response code	Strongly agree	Respondent agrees with "enabling factor" and can substantiate it based on his/her experience
		Cloud Data Management Interface(CDMI)		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
		Security	Security standards verified in data center by external auditors	Agree	Respondent agrees with "enabling factor" and can provide reasoning

Organizational	Business	Provider-centric interoperability and client-centric interoperability	Most of the interoparability responsibility should be with provider and minimum should be with customer.	Agree	Respondent agrees with "enabling factor" and can provide reasoning
	Process	Cloud Computing standardization Organizations	Helps in standardization which inturn helps in interoperability	Agree	Respondent agrees with "enabling factor" and can provide reasoning
	Service	Service Level agreement	Customer should review SLAs of all providers	Agree	Respondent agrees with "enabling factor" and can provide reasoning
	Data	Data liberation	Compliance	Agree	Respondent agrees with "enabling factor" and can provide reasoning
Additional comments	No additional comments				

Interview number :	int_AC2 - 1
Which function do you have within this company?	Senior consultant / Team lead (IK)
What is your highest, completed, education?	University
How many years of experience do you have within this company?	1
How many years of experience do you have in your current field?	8

What would be the role of the company you represent in a Platform Ecosystem?	Implementation partner
To what extent do you consider yourself familiar with interoperability of cloud platform ecosystems?	Technical lead in designing and developing applications in cloud platforms. IT architect for application development in cloud platforms.
How would you define Interoperability of cloud platform ecosystems? Based on your knowledge and experience, what are the main enabling factors for interoperability of cloud platform ecosystems?	Cloud interoperability is the ability of applications to exchange information and interact with cloud services from multiple cloud platforms. Main enabling factor is the business demands . For example, modular based IT architectures which provides agility to business need interoperable cloud applications.

Interoperability dimensions	Interoperability levels	Enabling factors	Interview transcript	Closed coding	Rationale for coding
conceptual	Business	Vendor lock-in avoidance	Possible to migrate applications to a different platform	Strongly agree	Respondent agrees with "enabling factor" and can substantiate it based on his/her experience
		Scalability	May be the main reason going for cloud interoperability	Strongly agree	Respondent agrees with "enabling factor" and can substantiate it based on his/her experience
		Regulations	May be relevant but not for the current customer	Neither agree nor disagree	Respondent mentions that regulations may be relevant but is unable to provide

					a proper justification regarding why it is an “enabling factor”
		Inter-organizational supply chain in networked enterprises	Enterprises are redefining their cloud strategy. Next generation multi-cloud strategies need to be smarter and agile.	Strongly agree	Respondent agrees with "enabling factor" and can substantiate it based on his/her experience
	Process	Alignment of cross organizational business process		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
		Supporting distributed business process	For example machine learning, OCR etc needs additional computing capacity and can be outsourced to cloud solutions	Strongly agree	Respondent agrees with "enabling factor" and can substantiate it based on his/her experience
	Service	Model-driven approach	An abstraction of a model needs to be defined. without reference to the technologies that may be used to implement it	Agree	Respondent agrees with "enabling factor" and can provide reasoning
		Cloud standardization projects		Neither agree nor disagree	Respondent has no opinion about

					the "enabling factor"
		Service oriented architecture	Only high-level request needs to be designed. You can have API calls.	Agree	Respondent agrees with "enabling factor" and can provide reasoning
	Data	Information interoperability	It is not important. It is upto business to make sense of data	Disagree	Respondent disagrees with "enabling factor" and can provide reasoning
		Platform-independent database abstraction layer		Neither agree nor disagree	Respondent has no opinion about the "enabling factor".
		Data Portability		Neither agree nor disagree	Respondent has no opinion about the "enabling factor".
		Trust model in cross-clouds applications	It makes things easier to implement secure communication between multiple cloud tenants	Agree	Respondent agrees with "enabling factor" and can provide reasoning
Technological	Business	Market Platform	It is important for subscribing to multiple services	Agree	Respondent agrees with "enabling factor" and can provide reasoning
		Aggregator		Neither agree nor disagree	Respondent has no opinion about

					the "enabling factor".
	Process	Cloud modelling framework and cloud modelling languages	We are using framework for RPA. Modelling framework helps in interoperability.	Strongly agree	Respondent agrees with "enabling factor" and can substantiate it based on his/her experience
		Microservices		Neither agree nor disagree	Respondent has no opinion about the "enabling factor".
	Service	Middleware	Middleware enables communication and data management	Agree	Respondent agrees with "enabling factor" and can provide reasoning
		Service broker		Neither agree nor disagree	Respondent has no opinion about the "enabling factor".
		Service description languages		Neither agree nor disagree	Respondent has no opinion about the "enabling factor".
		Agents for the service description and discovery		Neither agree nor disagree	Respondent has no opinion about the "enabling factor".

		Open libraries	Open libraries hosted in public URLs can enhance interoperability if they are used in application development.	Strongly agree	Respondent agrees with "enabling factor" and can substantiate it based on his/her experience
	Data	Semantic technologies		Neither agree nor disagree	Respondent has no opinion about the "enabling factor".
		Standardized APIs and data models	Definitely. Standarized APIs are data models support interoperability between cloud applications.	Strongly agree	Respondent agrees with "enabling factor" and can substantiate it based on his/her experience
		Cloud Data Management Interface(CDMI)		Neither agree nor disagree	Respondent has no opinion about the "enabling factor".
		Security	Security standards are used in development	Strongly agree	Respondent agrees with "enabling factor" and can substantiate it based on his/her experience

Organizational	Business	Provider-centric interoperability and client-centric interoperability	There are models where consumer makes one of the providers as the main supplier and makes that supplier to manage the interoperability with other cloud providers. Consumer is in contact only with the primary provider and in this case provider centric interoperability is beneficial for customer	Agree	Respondent agrees with "enabling factor" and can provide reasoning
	Process	Cloud Computing standardization Organizations		Neither agree nor disagree	Respondent has no opinion about the "enabling factor".
	Service	Service Level agreement	SLA outlines a mutual understanding of the services and responsibilities. Some of the SLAs are technically enforced also. These helps in interoperability.	Strongly agree	Respondent agrees with "enabling factor" and can substantiate it based on his/her experience
	Data	Data liberation	Exporting the data together with metadata to interpret the data format is important for interoperability of data between applications	Agree	Respondent agrees with "enabling factor" and can provide reasoning
Additional comments	Overall, the framework looks good. Cloud providers have maintenance calendars mentioning planned upgrades. Change management of organization should be aligned with this planning. So change management is a missing element in this framework.				

Interview number :	int_AC2 - 2

Which function do you have within this company?	Application developer (ND)
What is your highest, completed, education?	Bachelors
How many years of experience do you have within this company?	2
How many years of experience do you have in your current field?	2
What would be the role of the company you represent in a Platform Ecosystem?	Implementation partner
To what extent do you consider yourself familiar with interoperability of cloud platform ecosystems?	Application development in PaaS
How would you define Interoperability of cloud platform ecosystems? Based on your knowledge and experience, what are the main enabling factors for interoperability of cloud platform ecosystems?	Interoperability is the ability to migrate code from one environment to another without modification. Main enabling factor is digital transformation of organization. Moving towards cloud native applications and use of multi-cloud services.

Interoperability dimensions	Interoperability levels	Enabling factors	Interview transcript	Closed coding	Rationale for coding
conceptual	Business	Vendor lock-in avoidance	Definitely agree. Never know what happens with existing provider. Then you need to switch fast and efficiently	Agree	Respondent agrees with "enabling factor" and can provide reasoning
		Scalability	Additional storage and processing power can be easily provisioned to interoperable applications.	Agree	Respondent agrees with "enabling factor" and can provide reasoning
		Regulations	It is beneficial	Neither agree nor disagree	Respondent mentions that regulations may be relevant but is unable to provide

					a proper justification regarding why it is an “enabling factor”
		Inter-organizational supply chain in networked enterprises	This is related to use of multi-cloud services. For example, organization can connect to cloud network of vendors for easing the purchase process.	Strongly agree	Respondent agrees with "enabling factor" and can substantiate it based on his/her experience
	Process	Alignment of cross organizational business process		Neither agree nor disagree	Respondent has no opinion about the "enabling factor".
		Supporting distributed business process	Business process can be outsourced as a service to cloud providers.	Strongly agree	Respondent agrees with "enabling factor" and can substantiate it based on his/her experience
	Service	Model-driven approach	We use MVC (Model-View-Controller) model, which provides a separation of code between views that display, the data store and pure logic part . This helps in improving interoperability and less adjustments are needed.	Strongly agree	Respondent agrees with "enabling factor" and can substantiate it based on his/her experience

		Cloud standardization projects		Neither agree nor disagree	Respondent has no opinion about the "enabling factor".
		Service oriented architecture	Principles used in SOA is used for creating multi-cloud applications.	Agree	Respondent agrees with "enabling factor" and can provide reasoning
	Data	Information interoperability	It is not important. Information interoperability is on a logical layer and it is independent of whether it is cloud platform or not.	Disagree	
		Platform-independent database abstraction layer		Neither agree nor disagree	Respondent has no opinion about the "enabling factor".
		Data Portability		Neither agree nor disagree	Respondent has no opinion about the "enabling factor".
		Trust model in cross-clouds applications	Quiet beneficial from security perspective of multi cloud application	Agree	Respondent agrees with "enabling factor" and can provide reasoning
Technological	Business	Market Platform	Market place of cloud vendors are user friendly.	Neither agree nor disagree	Respondent mentions that “market platform” is user friendly but is unable to provide a proper justification

					regarding why it is an “enabling factor”
		Aggregator		Neither agree nor disagree	Respondent has no opinion about the "enabling factor".
	Process	Cloud modelling framework and cloud modelling languages	Cloud native developments are difficult to interoperate if standard frameworks are not followed.	Agree	Respondent agrees with "enabling factor" and can provide reasoning
		Microservices	Cloud native application is composed of many loosely coupled services. These loosely coupled services can support interoperability.	Strongly agree	Respondent agrees with "enabling factor" and can substantiate it based on his/her experience
	Service	Middleware	Middleware enables communication of distributed applications.	Agree	Respondent agrees with "enabling factor" and can provide reasoning
		Service broker		Neither agree nor disagree	Respondent has no opinion about the "enabling factor".
		Service description languages		Neither agree nor disagree	Respondent has no opinion about the "enabling factor".

		Agents for the service description and discovery		Neither agree nor disagree	Respondent has no opinion about the "enabling factor".
		Open libraries		Neither agree nor disagree	Respondent has no opinion about the "enabling factor".
	Data	Semantic technologies		Neither agree nor disagree	Respondent has no opinion about the "enabling factor".
		Standardized APIs and data models	Cloud API standards make it easier for organizations to use multiple clouds.	Agree	Respondent agrees with "enabling factor" and can provide reasoning
		Cloud Data Management Interface(CDMI)		Neither agree nor disagree	Respondent has no opinion about the "enabling factor".
		Security	Security standards are used in development of applications for implementing SSO, propogating authorization etc.	Agree	Respondent agrees with "enabling factor" and can provide reasoning
Organizational	Business	Provider-centric interoperability and client-centric interoperability		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"

	Process	Cloud Computing standardization Organizations	Follow standards, then it is compatible with other solutions. Can also create certified colutions	Agree	Respondent agrees with "enabling factor" and can provide reasoning
	Service	Service Level agreement	Should be aligned. It is important for customer to review SLAs before subscribing to services.	Agree	Respondent agrees with "enabling factor" and can provide reasoning
	Data	Data liberation		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
Additional comments	No comments				

Interview number :	int_AC1 - 2
Which function do you have within this company?	Application developer (MU)
What is your highest, completed, education?	Bachelors (technical)
How many years of experience do you have within this company?	4
How many years of experience do you have in your current field?	4
What would be the role of the company you represent in a Platform Ecosystem?	Implementation partner
To what extent do you consider yourself familiar with interoperability of cloud platform ecosystems?	Developed applications for multiple technologies for various cloud development platforms

How would you define Interoperability of cloud platform ecosystems? Based on your knowledge and experience, what are the main enabling factors for interoperability of cloud platform ecosystems?	Cloud application interoperability means cloud services can understand each other's APIs, configuration, authorization. Cloud Platform Interoperability means the ability to move applications and data between different platform providers. Main enabling factor is business requirements for additional functionalities. From a technical perspective cloud interoperability is facilitated by having interface standards between various PaaS providers

Interoperability dimensions	Interoperability levels	Enabling factors	Interview transcript	Closed coding	Rationale for coding
conceptual	Business	Vendor lock-in avoidance	Not too much hassle to switch between providers	Agree	Respondent agrees with "enabling factor" and can provide reasoning
		Scalability	On-demand provisioning is possible for multicloud applications.	Agree	Respondent agrees with "enabling factor" and can provide reasoning
		Regulations		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
		Inter-organizational supply chain in networked enterprises		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"

	Process	Alignment of cross organizational business process		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
		Supporting distributed business process	Cloud interoperability can potentially improve business process.	Agree	Respondent agrees with "enabling factor" and can provide reasoning
	Service	Model-driven approach	Model is abstract syntax representation.Runtime system will interpret the model.Some generator or compiler will take the model and generate the underlying elements	Strongly agree	Respondent agrees with "enabling factor" and can substantiate it based on his/her experience
		Cloud standardization projects		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
		Service oriented architecture	With SOA, the programming languages used by the service is decoupled from the cloud environment, making it easier to interoperate.	Agree	Respondent agrees with "enabling factor" and can provide reasoning
	Data	Information interoperability	There should be some standards regarding information interoperability	Agree	Respondent agrees with "enabling factor" and can provide reasoning

		Platform-independent database abstraction layer		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
		Data Portability		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
		Trust model in cross-clouds applications	Needed for setting up user access and trusted function calls between clouds.	Agree	Respondent agrees with "enabling factor" and can provide reasoning
Technological	Business	Market Platform		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
		Aggregator		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
	Process	Cloud modelling framework and cloud modelling languages	It supports application development lifecycle.Cloud Foundry's container-based architecture runs apps in any programming language over a variety of cloud service providers	Strongly agree	Respondent agrees with "enabling factor" and can substantiate it based on his/her experience
		Microservices	Microservices architecture in cloud computing is composed of many loosely coupled and independently deployable smaller components which supports interoperability	Agree	Respondent agrees with "enabling factor" and can provide reasoning

	Service	Middleware		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
		Service broker		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
		Service description languages		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
		Agents for the service description and discovery	Cloud agents are necessary for invoking communication	Agree	Respondent agrees with "enabling factor" and can provide reasoning
		Open libraries	Adding software library to a program to achieve more functionality and interoperability	Agree	Respondent agrees with "enabling factor" and can provide reasoning
	Data	Semantic technologies		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
		Standardized APIs and data models	Standardized APIs can decrease app development time and ensure quality and standardization	Agree	Respondent agrees with "enabling factor" and can provide reasoning

		Cloud Data Management Interface(CDMI)		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
		Security	Authorization token is important for authentication. Encryption can secure calls between multiple providers.	Agree	Respondent agrees with "enabling factor" and can provide reasoning
Organizational	Business	Provider-centric interoperability and client-centric interoperability		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
	Process	Cloud Computing standardization Organizations		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
	Service	Service Level agreement	SLAs are important	Agree	Respondent agrees with "enabling factor" and can provide reasoning
	Data	Data liberation	Export is easy. Importing or making sense of data together with metadata can be difficult	Agree	Respondent agrees with "enabling factor" and can provide reasoning
Additional comments	No comments				

Interview number :	int_C3
Which function do you have within this company?	Chief Information Security Officer (SA)
What is your highest, completed, education?	University
How many years of experience do you have within this company?	2
How many years of experience do you have in your current field?	16
What would be the role of the company you represent in a Platform Ecosystem?	Consumer
To what extent do you consider yourself familiar with interoperability of cloud platform ecosystems?	Overall responsible for IT security. Managed cloud migration projects and cloud integration with on-premise systems
How would you define Interoperability of cloud platform ecosystems? Based on your knowledge and experience, what are the main enabling factors for interoperability of cloud platform ecosystems?	Cloud interoperability leverage services from various cloud vendors. This is very important for organization to maintain its competitive edge.

Interoperability dimensions	Interoperability levels	Enabling factors	Interview transcript	Closed coding	Rationale for coding
conceptual	Business	Vendor lock-in avoidance	Cloud interoperability can avoid vendor lock-ins in the PaaS and IaaS layers. Applications can be hosted from datacenters of multiple vendors.	Strongly agree	Respondent agrees with "enabling factor" and can substantiate it based on his/her experience
		Scalability	If application is interoperable, it can be upscaled easily by providing additional VMs	Strongly agree	Respondent agrees with "enabling factor" and can substantiate it

					based on his/her experience
		Regulations	Regulations can enforce providers to adhere to standards that promote interoperability	Agree	Respondent agrees with "enabling factor" and can provide reasoning
		Inter-organizational supply chain in networked enterprises		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
	Process	Alignment of cross organizational business process	Once the business processes are streamlined, it can be checked what all activities can be outsourced to cloud.	Agree	Respondent agrees with "enabling factor" and can provide reasoning
		Supporting distributed business process	Same point as above. Once the business processes are streamlined, it can be checked what all activities can be outsourced to cloud.	Agree	Respondent agrees with "enabling factor" and can provide reasoning
	Service	Model-driven approach		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
		Cloud standardization projects	Standards and Industry best practices promote interoperability	Agree	Respondent agrees with "enabling factor" and can provide reasoning

		Service oriented architecture		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
	Data	Information interoperability	It is not necessary for information to be interoperable for cloud interoperability. There should be some semantics or data transformation to make information interoperable.	Disagree	Respondent disagrees with "enabling factor" and can provide reasoning
		Platform-independent database abstraction layer	Helps in migrating applications from one DB to another DB	Agree	Respondent agrees with "enabling factor" and can provide reasoning
		Data Portability		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
		Trust model in cross-clouds applications	Should setup trust model between interoperating clouds. Each participating cloud should be able to produce independent third-party examination reports that demonstrate how it achieves key compliance controls and objectives	Strongly agree	Respondent agrees with "enabling factor" and can substantiate it based on his/her experience
Technological	Business	Market Platform		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
		Aggregator		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"

	Process	Cloud modelling framework and cloud modelling languages	Standards and Industry best practices promote interoperability	Agree	Respondent agrees with "enabling factor" and can provide reasoning
		Microservices		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
	Service	Middleware	Can act as a translation layer between cloud connections	Agree	Respondent agrees with "enabling factor" and can provide reasoning
		Service broker		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
		Service description languages		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
		Agents for the service description and discovery		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
		Open libraries	Constant vulnerability assessment and patching/upgrade needs to be done when using open libraries	Agree	Respondent agrees with "enabling factor" and can provide reasoning

	Data	Semantic technologies		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
		Standardized APIs and data models	Standardized APIs should support various authentication and authorization features	Agree	Respondent agrees with "enabling factor" and can provide reasoning
		Cloud Data Management Interface(CDMI)	Common administration interface can significantly help administrators and security team.	Agree	Respondent agrees with "enabling factor" and can provide reasoning
		Security	Data encryption in transit and at rest are important. GDPR and other privacy regulations also needs to be considered.	Strongly agree	Respondent agrees with "enabling factor" and can substantiate it based on his/her experience
Organizational	Business	Provider-centric interoperability and client-centric interoperability		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
	Process	Cloud Computing standardization Organizations		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
	Service	Service Level agreement	SLAs should be reviewed. Risk assessment and business impact analysis should also be performed.	Agree	Respondent agrees with

			Process should be in place for disaster recovery, business continuity plan etc		"enabling factor" and can provide reasoning
	Data	Data liberation	Data security should be considered when exporting/importing data to and from cloud	Agree	Respondent agrees with "enabling factor" and can provide reasoning
Additional comments	Topics regarding governance of interoperable clouds is missing.				

Interview number :	int_AC1 - 1
Which function do you have within this company?	Director Business Consulting (GE)
What is your highest, completed, education?	Business economist (Diploma)
How many years of experience do you have within this company?	6
How many years of experience do you have in your current field?	22
What would be the role of the company you represent in a Platform Ecosystem?	Implementation partner / consulting
To what extent do you consider yourself familiar with interoperability of cloud platform ecosystems?	Developed cloud strategy for multiple clients in several roles such as liaison between business and IT, techno functional lead, consulting partner etc
How would you define Interoperability of cloud platform ecosystems? Based on your knowledge and experience, what are the main enabling factors for interoperability of cloud platform ecosystems?	Cloud interoperability means each cloud vendor in multicloud infrastructure is compatible with each other and a user can reap the benefits of each provider's services Organizations need to avoid information silos and fragmented processes while moving into the cloud. This is the main enabler for cloud interoperability. Some

	organizations follow cloud first strategy. Cloud interoperability is essential for these organizations to have a single source of truth, accurate data.

Interoperability dimensions	Interoperability levels	Enabling factors	Interview transcript	Closed coding	Rationale for coding
conceptual	Business	Vendor lock-in avoidance	Cost and effort of switching to a new vendor is less when there is interoperable cloud architceture	Strongly agree	Respondent agrees with "enabling factor" and can substantiate it based on his/her experience
		Scalability	Possible to scale computing power when the application layer is interoperable with IaaS layer	Strongly agree	Respondent agrees with "enabling factor" and can substantiate it based on his/her experience
		Regulations	Regulations can indeed prevent monopoly of big cloud players.	Agree	Respondent agrees with "enabling factor" and can provide reasoning
		Inter-organizational supply chain in networked enterprises	Interoperable cloud applications can avoid information silos and provide the user with single source of truth	Agree	Respondent agrees with "enabling factor" and can provide reasoning

	Process	Alignment of cross organizational business process	It is not a prerequisite that business process needs to be harmonized before the organization moves to cloud	Disagree	Respondent agrees with "enabling factor" and can provide reasoning
		Supporting distributed business process	Interoperable cloud applications can provide the user with single source of truth	Agree	Respondent agrees with "enabling factor" and can provide reasoning
	Service	Model-driven approach		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
		Cloud standardization projects		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
		Service oriented architecture	SoA is composed of loosely coupled services. Interoperable cloud applications are loosely coupled via APIs	Agree	Respondent agrees with "enabling factor" and can provide reasoning
	Data	Information interoperability	Yes it is required for single source of truth for data from multiple services	Agree	Respondent disagrees with "enabling factor" and can provide reasoning
		Platform-independent database abstraction layer		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"

		Data Portability		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
		Trust model in cross-clouds applications	Security is a top priority for cloud providers	Strongly agree	Respondent agrees with "enabling factor" and can substantiate it based on his/her experience
Technological	Business	Market Platform	This model allows consumers to subscribe for various services. It may support interoperability when the services are from same provider. When the services are from different providers, it does not necessarily support interoperability.	Neither agree nor disagree	Respondent mentions that this "enabling factor" can support interoperability only on specific cases and not always.
		Aggregator		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
	Process	Cloud modelling framework and cloud modelling languages		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
		Microservices	Same explanation as for SoA	Agree	Respondent agrees with "enabling factor" and can provide reasoning

	Service	Middleware	Various middleware technologies are used for integrating on-premise data with cloud services	Agree	Respondent agrees with "enabling factor" and can provide reasoning
		Service broker		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
		Service description languages		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
		Agents for the service description and discovery		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
		Open libraries		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
	Data	Semantic technologies		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
		Standardized APIs and data models	Standardized APIs and data models are important for facilitating interoperability between providers.	Agree	Respondent agrees with "enabling factor" and can provide reasoning

		Cloud Data Management Interface(CDMI)		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
		Security	Authentication, authorization, encryption etc are needed for data security of services from different providers	Strongly agree	Respondent agrees with "enabling factor" and can substantiate it based on his/her experience
Organizational	Business	Provider-centric interoperability and client-centric interoperability		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
	Process	Cloud Computing standardization Organizations		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
	Service	Service Level agreement	This is one of the first things which needs to be checked in detail. High Availability and QoS mentioned in SLAs are important for interoperability	Strongly agree	Respondent agrees with "enabling factor" and can substantiate it based on his/her experience
	Data	Data liberation		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"

Additional comments	To be honest, there is no need for a specific framework for cloud applications. The existing ITSM framework can be used after modifying with additional cloud specific elements. This framework can be used as a checklist for preparation of cloud interoperability projects.

Interview number :	int_C4
Which function do you have within this company?	Group Leader - Digital Platforms(JdB)
What is your highest, completed, education?	HBO (Technische Informatica)
How many years of experience do you have within this company?	16
How many years of experience do you have in your current field?	6
What would be the role of the company you represent in a Platform Ecosystem?	Consumer
To what extent do you consider yourself familiar with interoperability of cloud platform ecosystems?	As group leader for Digital Process Excellence program, I have been driving digital transformation strategy including cloud adoption and customer collaboration.
How would you define Interoperability of cloud platform ecosystems? Based on your knowledge and experience, what are the main enabling factors for interoperability of cloud platform ecosystems?	Interoperability in the context of cloud environments, is the ability of applications to work with multiple cloud platforms and facilitate the exchange of information and data across them. Main enabling factor is cost-benefit analysis to migrate on-premises datacenters to cloud. Another enabling factor is innovation – for example cloud analytical applications, customer collaboration in cloud etc

Interoperability dimensions	Interoperability levels	Enabling factors	Interview transcript	Closed coding	Rationale for coding

conceptual	Business	Vendor lock-in avoidance	A multi-cloud strategy where an organization uses two or more cloud services from different vendors supporting interoperability can avoid vendor lock-in	Agree	Respondent agrees with "enabling factor" and can provide reasoning
		Scalability	An interoperable cloud can manage the increasing demands of computing power	Strongly agree	Respondent agrees with "enabling factor" and can substantiate it based on his/her experience
		Regulations		Neither agree nor disagree	Respondent agrees with "enabling factor" and can provide reasoning
		Inter-organizational supply chain in networked enterprises	Supports customer collaboration with B2B cloud network	Agree	Respondent agrees with "enabling factor" and can provide reasoning
	Process	Alignment of cross organizational business process	Not see the value in the alignment of business process, before moving to cloud	Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
		Supporting distributed business process	Business process outsourcing to cloud vendors is possible via interoperable cloud	Agree	Respondent agrees with "enabling factor" and can provide reasoning

	Service	Model-driven approach		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
		Cloud standardization projects		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
		Service oriented architecture	SoA architecture enables interoperability of cloud services	Agree	Respondent agrees with "enabling factor" and can provide reasoning
	Data	Information interoperability		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
		Platform-independent database abstraction layer		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
		Data Portability		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
		Trust model in cross-clouds applications	Secure authentication mechanism can be implemented only between clouds which has a trust relationship	Strongly agree	Respondent agrees with "enabling factor" and can substantiate it based on his/her experience

Technological	Business	Market Platform		Neither agree nor disagree	Respondent mentions that this "enabling factor" can support interoperability only on specific cases and not always.
		Aggregator		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
	Process	Cloud modelling framework and cloud modelling languages		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
		Microservices	Microservices enables interoperability of cloud services similar to SoA	Agree	Respondent agrees with "enabling factor" and can provide reasoning
	Service	Middleware	Middleware or cloud agents or cloud connectors are needed for communication between different clouds	Agree	Respondent agrees with "enabling factor" and can provide reasoning
		Service broker		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
		Service description languages		Neither agree nor disagree	Respondent has no opinion about

					the "enabling factor"
		Agents for the service description and discovery		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
		Open libraries	There can be common libraries for standard controls which enable interoperability	Agree	Respondent has no opinion about the "enabling factor"
	Data	Semantic technologies		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
		Standardized APIs and data models	Standard APIs are important for developing applications which interact with multiple cloud providers	Agree	Respondent agrees with "enabling factor" and can provide reasoning
		Cloud Data Management Interface(CDMI)		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
		Security	Already mentioned. Security is important for authentication and authorization between cross cloud providers	Strongly agree	Respondent agrees with "enabling factor" and can substantiate it based on his/her experience

Organizational	Business	Provider-centric interoperability and client-centric interoperability		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
	Process	Cloud Computing standardization Organizations		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
	Service	Service Level agreement	Agreement between a cloud service provider and a customer is very important factor in interoperability. This is the first thing to review together with business unit managers and IT procurement manager	Strongly agree	Respondent agrees with "enabling factor" and can substantiate it based on his/her experience
	Data	Data liberation		Neither agree nor disagree	Respondent has no opinion about the "enabling factor"
Additional comments	Framework covers a lot of aspects. In the organizational aspect, you can add some elements like setting up of cloud center of excellence.				

Appendix K Data synthesis of interview transcripts

Interoperability dimensions	Interoperability levels	Enabling factors	Main comments from interviews which validated the enabling factor (Interview identification code in bracket)	Main comments from interviews which did not validate the enabling factor (Interview identification code in bracket)	Remarks
conceptual	Business	Vendor lock-in avoidance	Depends on SaaS or PaaS or IaaS. For SaaS, no easy viable solution. Even if you have another vendor, the migration is long and heavy process. The more sophisticated and specialized tool you need, you have less options to avoid lock-in. For IaaS and PaaS Vendor lock-in avoidance is an enabling factor (int_C1) Locked-in to one provider is a form of monopoly for the vendor. It should be possible to interoperate with other vendors (int_C2) Possible to migrate applications to a different platform (int_AC2 – 1) Definitely agree. Never know what happens with existing provider. Then you need to switch fast and efficiently (int_AC2 – 2) Not too much hassle to switch between providers (int_AC1 – 2)		All the eight respondents positively validated this enabling factor. One respondent has mentioned that this enabling factor is not applicable for SaaS but applicable for IaaS and PaaS. Other respondents did not distinguish between cloud models.

			Cloud interoperability can avoid vendor lock-ins in the PaaS and IaaS layers. Applications can be hosted from datacenters of multiple vendors. (int_C3) Cost and effort of switching to a new vendor is less when there is interoperable cloud architecture (int_AC1 – 1) A multi-cloud strategy where an organization uses two or more cloud services from different vendors supporting interoperability can avoid vendor lock-in (int_C4)		
		Scalability	Moving to IaaS to avoid cost. Less lead time for IaaS (int_C1) When the application is interoperable, resources can be added on the infrastructure layer on the fly and scale as rapidly as the customers require. (int_C2) May be the main reason going for cloud interoperability (int_AC2 – 1) Additional storage and processing power can be easily provisioned to interoperable applications. (int_AC2 – 2)		All the eight respondents positively validated this enabling factor. One respondent has mentioned that this is possibly the main enabling factor for cloud interoperability

			Not too much hassle to switch between providers (int_AC1 – 2) If application is interoperable, it can be upscaled easily by providing additional VMs (int_C3) Possible to scale computing power when the application layer is interoperable with IaaS layer (int_AC1 – 1) An interoperable cloud can manage the increasing demands of computing power (int_C4)		
		Regulations	Regulations can enforce providers to adhere to standards that promote interoperability (int_C3) Regulations can indeed prevent monopoly of big cloud players. (int_AC1 – 1)	Regulations are impacting everybody. Not as important for interoperability. It is helping but not an enabling factor (int_C1)	Two respondents have positively validated this enabling factor. One respondent disagreed with this enabling factor (negative response). Five respondents did not provide any substantial answer and did not validate this enabling factor.(neither agreed or disagreed)
		Inter-organizational supply chain in networked enterprises	Yes it promotes cloud interoperability. Interoperable cloud allows suppliers and buyers to connect and do business on a single platform (int_C2)	There is no strict need to have specifically designed business process to have cloud solutions.It is otherway around. Cloud can support busines process. Cloud can provide fexibility in	Five respondents have positively validated this enabling factor. One respondent disagreed with this enabling factor (negative response). Two respondents

			Enterprises are redefining their cloud strategy. Next generation multi-cloud strategies need to be smarter and agile.(int_AC2 – 1) This is related to use of multi-cloud services. For example, organization can connect to cloud network of vendors for easing the purchase process. (int_AC2 – 2) Interoperable cloud applications can avoid information silos and provide the user with single source of truth (int_AC1 – 1) Supports customer collaboration with B2B cloud network (int_C4)	business process. Can help in organic growth rather than in a revolution. (int_C1)	did not provide any substantial answer and did not validate this enabling factor.(neither agreed or disagreed)
	Process	Alignment of cross organizational business process	Business process modelling and interoperable cloud solutions should go hand in hand. There should be a feasibiity study.(int_C2) Once the business processes are streamlined, it can be checked what all activities can be outsourced to cloud. (int_C3)	There is no strict need to have specifically designed business process to have cloud solutions.It is otherway around. Cloud can support busines process. Cloud can provide fexibility in business process. Can help in organic growth rather than in a revolution. (int_C1) It is not a prerequisite that business process needs to be harmonized before the organization moves to cloud (int_AC1 – 1)	Two respondents have positively validated this enabling factor. Two respondents disagreed with this enabling factor (negative response). Four respondents did not provide any substantial answer and did not validate this enabling factor.(neither agreed or disagreed)

		Supporting distributed business process	Business process modelling and interoperable cloud solutions should go hand in hand. There should be a feasibiity study.(int_C2) For example machine learning, OCR etc needs additional computing capacity and can be outsourced to cloud solutions (int_AC2 – 1) Business process can be outsourced as a service to cloud providers. (int_AC2 – 2) Cloud interoperability can potentially improve business process. (int_AC1 – 2) Once the business processes are streamlined, it can be checked what all activities can be outsourced to cloud. (int_C3) Interoperable cloud applications can provide the user with single source of truth (int_AC1 – 1) Business process outsourcing to cloud vendors is possible via interoperable cloud (int_C4)	There is no strict need to have specifically designed business process to have cloud solutions.It is otherway around. Cloud can support busines process. Cloud can provide fexibility in business process. Can help in organic growth rather than in a revolution. (int_C1)	Seven respondents have positively validated this enabling factor. One respondent disagreed with this enabling factor (negative response).

	Service	Model-driven approach	We have seen in previous developmental architecture. MDA is not cloud specific approach. It is a software design approach. It is suitable for cloud native applications also.(int_C2) An abstraction of a model needs to be defined. without reference to the technologies that may be used to implement it (int_AC2 – 1) We use MVC (Model-View-Controller) model, which provides a separation of code between views that display, the data store and pure logic part . This helps in improving interoperability and less adjustments are needed. (int_AC2 – 2) Model is abstract syntax representation.Runtime system will interpret the model.Some generator or compiler will take the model and generate the underlying elements (int_AC1 – 2)		Four respondents have positively validated this enabling factor. Four respondents did not provide any substantial answer and did not validate this enabling factor.(neither agreed or disagreed)
		Cloud standardization projects	Standards and Industry best practices promote interoperability (int_C3)		One respondent has positively validated this enabling factor. Seven respondents did not provide any substantial answer and did not validate

					this enabling factor.(neither agreed or disagreed)
		Service oriented architecture	SoA can increase complexity. Interoperability can be result of synergy. But at the expense of complexity and security. (int_C1) API mapping is important. General enterprise architect principle. Cloud is just an extension. (int_C2) Only high-level request needs to be designed. You can have API calls. (int_AC2 – 1) Principles used in SOA is used for creating multi-cloud applications. (int_AC2 – 2) With SOA, the programming languages used by the service is decoupled from the cloud environment, making it easier to interoperate. (int_AC1 – 2) SoA is composed of loosely coupled services. Interoperable cloud applications are loosely coupled via APIs (int_AC1 – 1) SoA architecture enables interoperability of cloud services		Seven respondents have positively validated this enabling factor. One respondent did not provide any substantial answer and did not validate this enabling factor.(neither agreed or disagreed)

			(int_C4)		
	Data	Information interoperability	Should be some standard mechanism for interoperability. Mapping tables can be used for this. (int_C2) There should be some standards regarding information interoperability (int_AC1 – 2) Yes it is required for single source of truth for data from multiple services (int_AC1 – 1)	Business semantics are important. It is not a big factor for interoperability currently but may be in future. (int_C1) It is not important. It is upto business to make sense of data (int_AC2 – 1) It is not important. Information interoperability is on a logical layer and it is independent of whether it is cloud platform or not. (int_AC2 – 2) It is not necessary for information to be interoperable for cloud interoperability. There should be some semantics or data transformation to make information interoperable. (int_C3)	Three respondents have positively validated this enabling factor. Four respondents disagreed with this enabling factor (negative response). One respondent did not provide any substantial answer and did not validate this enabling factor.(neither agreed or disagreed)
		Platform-independent database abstraction layer	DB layer is independent of application layer.Can avoid lock-in with one database (int_C2) Helps in migrating applications from one DB to another DB (int_C3)		Two respondents have positively validated this enabling factor. Six respondents did not provide any substantial answer and did not validate this enabling factor.(neither agreed or disagreed)

		Data Portability		Not necessarily. You can have intermediary which can do the translation for you.(int_C1)	One respondent disagreed with this enabling factor (negative response). Seven respondents did not provide any substantial answer and did not validate this enabling factor.(neither agreed or disagreed)
		Trust model in cross-clouds applications	The more secure the better. One of the core things for interoperable solution. If you cannot trust other party, you cannot have interoperable solution (int_C1) Required for SSO (int_C2) It makes things easier to implement secure communication between multiple cloud tenants (int_AC2 – 1) Quiet beneficial from security perspective of multi cloud application (int_AC2 – 2) Needed for setting up user access and trusted function calls between clouds. (int_AC1 – 2)		All the eight respondents positively validated this enabling factor.

			Should setup trust model between interoperating clouds. Each participating cloud should be able to produce independent third-party examination reports that demonstrate how it achieves key compliance controls and objectives (int_C3) Security is a top priority for cloud providers (int_AC1 – 1) Secure authentication mechanism can be implemented only between clouds which has a trust relationship (int_C4)		
Technological	Business	Market Platform	For smaller companies which do not have capabilities in-house. Enables to use more and more cloud application from market place. These services are usually interoperable. Downside is vendor lock-in (int_C1) Key principle for integration. One development platform, you can subscribe for multiple applications (int_C2) It is important for subscribing to multiple services (int_AC2 – 1)		Three respondents have positively validated this enabling factor. Five respondents did not provide any substantial answer and did not validate this enabling factor.(neither agreed or disagreed). One respondent has mentioned that this model allows consumers to subscribe for various services. It may support interoperability when the services are from same provider. When the services

					are from different providers, it does not necessarily support interoperability.
		Aggregator			None of the respondents provides any substantial answer and did not validate this enabling factor.(neither agreed or disagreed)
	Process	Cloud modelling framework and cloud modelling languages	Reduce development time and time to market. To make standardization of development, interoperating party only needs to know only your header details. Minimum impact when there is a change. (int_C2) We are using framework for RPA. Modelling framework helps in interoperability. (int_AC2 – 1) Cloud native developments are difficult to interoperate if standard frameworks are not followed. (int_AC2 – 2) It supports application development lifecycle.Cloud Foundry's container-based architecture runs apps in any programming language over a variety of cloud service providers (int_AC1 – 2)		Five respondents have positively validated this enabling factor. Three respondents did not provide any substantial answer and did not validate this enabling factor.(neither agreed or disagreed)

			Standards and Industry best practices promote interoperability (int_C3)		
		Microservices	Same as that of SoA. It can provide interoperability at the expense of complexity and security. (int_C1) Cloud native application is composed of many loosely coupled services. These loosely coupled services can support interoperability. (int_AC2 – 2) Microservices architecture in cloud computing is composed of many loosely coupled and independently deployable smaller components which supports interoperability (int_AC1 – 2) Interoperable cloud applications are loosely coupled via APIs (int_AC1 – 1) Microservices enables interoperability of cloud services similar to SoA (int_C4)		Five respondents have positively validated this enabling factor. Three respondents did not provide any substantial answer and did not validate this enabling factor.(neither agreed or disagreed)
	Service	Middleware	It is used quite heavily (int_C1)		Seven respondents have positively validated this enabling factor. One respondent did not provide

			Important component for understanding sender structure and converting to receiver structure (like adapter). Just map it. (int_C2) Middleware enables communication and data management (int_AC2 – 1) Middleware enables communication of distributed applications. (int_AC2 – 2) Can act as a translation layer between cloud connections (int_C3) Various middleware technologies are used for integrating on-premise data with cloud services (int_AC1 – 1) Middleware or cloud agents or cloud connectors are needed for communication between different clouds (int_C4)		any substantial answer and did not validate this enabling factor.(neither agreed or disagreed)
		Service broker			None of the respondents provides any substantial answer and did not validate

					this enabling factor.(neither agreed or disagreed)
		Service description languages			None of the respondents provides any substantial answer and did not validate this enabling factor.(neither agreed or disagreed)
		Agents for the service description and discovery	Cloud agents are necessary for invoking communication (int_AC1 – 2)		One respondent has positively validated this enabling factor. Seven respondents did not provide any substantial answer and did not validate this enabling factor.(neither agreed or disagreed)
		Open libraries	For developers, it is very important (int_C1) Open structure - helps in interoperability (int_C2) Open libraries hosted in public URLs can enhance interoperability if they are used in application development. (int_AC2 – 1) Adding software library to a program to achieve more functionality and interoperability (int_AC1 – 2) Constant vulnerability assessment and patching/upgrade needs to be done when using open libraries		Six respondents have positively validated this enabling factor. Two respondents did not provide any substantial answer and did not validate this enabling factor.(neither agreed or disagreed)

			(int_C3) There can be common libraries for standard controls which enable interoperability (int_C4)		
	Data	Semantic technologies			None of the respondents provides any substantial answer and did not validate this enabling factor.(neither agreed or disagreed)
		Standardized APIs and data models	Explore standard APIs by providing test data or input and checking the HTTP response code (int_C2) Definitely. Standarized APIs are data models support interoperability between cloud applications. (int_AC2 – 1) Cloud API standards make it easier for organizations to use multiple clouds. (int_AC2 – 2) Standardized APIs can decrease app development time and ensure quality and standardization (int_AC1 – 2)		Seven respondents have positively validated this enabling factor. One respondent did not provide any substantial answer and did not validate this enabling factor.(neither agreed or disagreed)

			Standardized APIs should support various authentication and authorization features (int_C3) Standardized APIs and data models are important for facilitating interoperability between providers. (int_AC1 – 1) Standard APIs are important for developing applications which interact with multiple cloud providers (int_C4)		
		Cloud Data Management Interface(CDMI)	Yes for sure. This helps cloud administrators to administer multiple clouds from same console. So this is supporting interoperability from an admin perspective. (int_C1) Common administration interface can significantly help administrators and security team. (int_C3)		Two respondents have positively validated this enabling factor. Six respondents did not provide any substantial answer and did not validate this enabling factor.(neither agreed or disagreed)
		Security	Strong encryption, Authentication, Authorization are needed for securely transferring data across cloud platforms (int_C1) Security standards verified in data center by external auditors		All the eight respondents positively validated this enabling factor.

			(int_C2) Security standards are used in development (int_AC2 – 1) Security standards are used in development of applications for implementing SSO, propogating authorization etc. (int_AC2 – 2) Authorization token is important for authentication. Encryption can secure calls between multiple providers. (int_AC1 – 2) Data encryption in transit and at rest are important. GDPR and other privacy regulations also needs to be considered. (int_C3) Authentication, authorization, encryption etc are needed for data security of services from different providers (int_AC1 – 1) Security is important for authentication and authorization between cross cloud providers (int_C4)		

Organizational	Business	Provider-centric interoperability and client-centric interoperability	Depends on the application because you might want the provider to be responsible for critical ones. Mission critical should be provider centric. For more control, client centric is more important. (int_C1) Most of the interoparability responsibility should be with provider and minimum should be with customer. (int_C2) There are models where consumer makes one of the providers as the main supplier and makes that supplier to manage the interoperability with other cloud providers. Consumer is in contact only with the primary provider and in this case provider centric interoperability is beneficial for customer (int_AC2 - 1)		Three respondents have positively validated this enabling factor. Five respondents did not provide any substantial answer and did not validate this enabling factor.(neither agreed or disagreed)
	Process	Cloud Computing standardization Organizations	Good to have some organization setting up standards. I am not familiar. Big companies may not like restrictions imposed by standards organization. Smaller players might adhere to standards and market themselves as "standards compliant" solution. (int_C1)		Three respondents have positively validated this enabling factor. Five respondents did not provide any substantial answer and did not validate this enabling factor.(neither agreed or disagreed)

			Helps in standardization which inturn helps in interoperability (int_C2) Follow standards, then it is compatible with other solutions.Can also create certified colutions (int_AC2 – 2)		
	Service	Service Level agreement	Extremely important. One of the things to be reviewed first. (int_C1) Customer should review SLAs of all providers (int_C2) SLA outlines a mutual understanding of the services and responsibilities. Some of the SLAs are technically enforced also. These helps in interoperability. (int_AC2 – 1) Should be aligned. It is important for customer to review SLAs before subscribing to services. (int_AC2 – 2) SLAs are important (int_AC1 – 2) SLAs should be reviewed. Risk assessment and business impact analysis should also be performed.		All the eight respondents positively validated this enabling factor.

			Process should be in place for disaster recovery, business continuity plan etc (int_C3) This is one of the first things which needs to be checked in detail. High Availability and QoS mentioned in SLAs are important for interoperability (int_AC1 – 1) Agreement between a cloud service provider and a customer is very important factor in interoperability. This is the first thing to review together with business unit managers and IT procurement manager (int_C4)		
	Data	Data liberation	One thing about data is format. You may be able to export but if you do not know metadata, you will not be able to use it. Proper documentation and following standards is very important. (int_C1) This can be a compliance requirement for interoperable cloud applications (int_C2) Exporting the data together with metadata to interpret the data format is important for interoperability of data between applications (int_AC2 – 1)		Five respondents have positively validated this enabling factor. Three respondents did not provide any substantial answer and did not validate this enabling factor.(neither agreed or disagreed)

			Export is easy. Importing or making sense of data together with metadata can be difficult (int_AC1 – 2) Data security should be considered when exporting/importing data to and from cloud (int_C3)		

Appendix L Details of responses for confirmatory part of the interviews

The following section elaborates on our findings regarding the responses for confirmatory part of the interviews.

The interoperability of business

Results on interoperability of business is discussed below, for technological and organizational dimensions.

Technological dimension

Under the technological dimension, the enabling factors "Market Platform" and "Aggregator" were mentioned in the framework. Three respondents have positively validated the enabling factor **Market Platform**. One of the arguments supporting this enabling factor is that "*For smaller companies which do not have capabilities in-house, Market Platform enables to use more and more cloud application from marketplace. These services are usually interoperable.*" (interview code int_C1). Another key response which positively validated this enabling factor is that "*You can subscribe for multiple applications from one development platform*"(interview code int_C2).Since only three respondents out of eight respondents have positively validated this enabling factor, it appears that Market Place is not commonly in use and hence not included in the practical framework. Other enabling factor "**Aggregator**" which was mentioned under the technical dimension was surprisingly not validated by any of the respondents. None of the respondents were familiar with "Aggregator". As per the literature, "Aggregator" aggregates many small and modular services into value-added, complex solutions for certain needs. However, none of the respondents were aware of any "Aggregator" in cloud platform ecosystems. It should be noted that respondents were familiar with combining of modular services as part of SoA (Service Oriented Architecture) which is explained under the section interoperability of services.

Organizational dimension

The enabling factor "**Provider-centric interoperability and client-centric interoperability**" is mentioned in the framework as part of organizational level interoperability. Three respondents have positively validated this enabling factor. One of the valid responses was that "*mission critical applications should be based on client-centric interoperability so that client has full control on the services*." (interview code int_C1). Another respondent has mentioned "*There are models where consumer makes one of the providers as the main supplier and makes that supplier to manage the interoperability with other cloud providers. Consumer is in contact only with the primary provider and in this case provider centric interoperability is beneficial for customer*" (interview code int_AC2 - 1). Even though all respondents are aware of the "Provider-centric interoperability and client-centric interoperability", only three of the respondents considered it was relevant for enabling interoperability. Since majority of the respondents did not find a relation between this enabling factor and cloud interoperability, this element is not validated in the empirical study and will not be included in the final practical framework.

The interoperability of processes

Results on interoperability of process is discussed below, for technological and organizational dimensions.

Technological dimension

On the technological layer "**Cloud modelling framework and cloud modelling languages**" and "**Microservices**" were validated by respondents as enabling factors. Regarding "Cloud modelling framework and cloud modelling languages" respondents have positively validated this element by giving supporting statements such as "*Reduce development time and time to market*" (interview code int_C2), "*Modelling framework helps in interoperability*" (interview code int_AC2 – 1), "*It supports application development lifecycle*" (interview code int_AC1 – 2) and "*Standards and Industry best practices promote interoperability*" (interview code int_C3). Therefore, this element is added in the final practical framework. The enabling factor "Microservices" is also validated by respondents. One of the responses which proved how microservices can support interoperability is that "*Microservices architecture in cloud computing is composed of many loosely coupled and independently deployable smaller components which supports interoperability*" (interview code int_AC1 – 2). One of the respondents has mentioned that "*microservices can provide interoperability at the expense of complexity and security*" (interview code int_C1). Even though it is a valid concern that microservices can increase the complexity of overall architecture and can result in additional security concerns, five respondents have positively validated that it is an enabling factor for interoperability. Hence it is included in the final practical framework.

Organizational dimension

"**Cloud Computing standardization Organizations**" was mentioned in the framework as an enabling factor for interoperability of processes in the organizational layer. One of the respondents commented about this enabling factor that "*Big companies may not like restrictions imposed by standards organization. Smaller players might adhere to standards and market themselves as standards compliant provider*" (interview code int_C1). Another respondent has mentioned that "*Follow standards, then it is compatible with other solutions*" (interview code int_AC2 – 2). Only three out of eight respondents validated this enabling factor. This could be because of the fact that the standards organizations in cloud computing are not yet popular in the industry. This element is not included in the final framework due to low number of respondents who validated this element. Further research can provide more insight into this element.

The interoperability of services

Results on interoperability of services is discussed below, for technological and organizational dimensions.

Technological dimension

On the technological layer, "**Open libraries**" is validated as an important enabling factor by most of the respondents. Seven respondents have positively validated this enabling factor mentioning that "*it is very important for developers*" (interview code int_C1) and "*Adding software library to a program helps to achieve more functionality and interoperability*" (interview code int_AC1 – 2). One respondent has raised the concern that "*periodic vulnerability assessment and patching/upgrade needs to be done when using open libraries*" (interview code int_C3). Since this enabling factor is overall positively validated by most of the respondents, it is included in the final practical framework."**Service broker**", "**Service description languages**" and "**Agents for the service description and discovery**" were not validated as enabling factors on technological layer. It could be because of the theoretical nature of these enabling factors, majority of the respondents did not recognize these enabling factors in practical implementation, which resulted in these factors being not validated.

Organizational dimension

"**Service Level agreement**" which is mentioned as an enabling factor for interoperability of services on the organizational layer, was validated by most of the respondents as one of the important enabling factors. Respondents mentioned that this enabling factor is "*extremely important*" (interview code int_C1) and is "*one of the things to be reviewed first*" (interview code int_AC1 – 1). As per the respondents "*High Availability and QoS mentioned in SLAs are important for interoperability*" (interview code int_AC1 – 1). This element is included in the final practical framework.

The interoperability of data

Results on interoperability of data is discussed below, for technological and organizational dimensions.

Technological dimension

On the technological layer, the factors "Standardized APIs and data models" and "Security" were validated by most of the respondents. The feedback regarding "**Standardized APIs and data models**" was that "*Cloud API standards make it easier for organizations to use multiple clouds*" (interview code int_AC2 – 2). The feedback from interviews reflected the idea that "*Standardized APIs and data models are important for facilitating interoperability between providers*" (interview code int_AC1 – 1). Therefore, this element is included in the final framework. About the enabling factor "**security**", all the respondents positively validated this element. Notable responses from the respondents included "*Strong encryption, Authentication, Authorization are needed for securely transferring data across cloud platforms*" (interview code int_C1). Another feedback was that "*Security standards are used in development of applications for implementing SSO, propagating authorization etc*" (interview code int_AC2 – 1) and "*Data encryption in transit and at rest are important.*" (interview code int_C3). Enabling factor "security" is therefore included in the practical framework. "**Semantic technologies**" and "**Cloud Data Management Interface (CDMI)**" were not validated. This could be because of the lack of expertise of respondents in these areas, as these elements are mainly concerning analytics and administration of cloud applications respectively and the research population did not have any analytics or cloud administration expert.

Organizational dimension

On an organizational layer, the enabling factor "**Data liberation**" was validated by respondents. One of the notable feedbacks regarding this enabling factor was that "*One thing about data is format. You may be able to export but if you do not know metadata, you will not be able to use it*." (interview code int_C1). It was also mentioned that "*Exporting the data together with metadata to interpret the data format is important for interoperability of data between applications"* (interview code int_AC2 – 1). One of the valid concerns regarding this element was that "*Data security should be considered when exporting/importing data to and from cloud*" (interview code int_C3)

Appendix M Empirical framework

Interoperability dimensions	Interoperability levels	Enabling factors	Comments
conceptual	Business	Vendor lock-in avoidance	This element is validated and will remain in final practical framework
		Scalability	This element is validated and will remain in final practical framework
		Regulations	This element is not validated and needs to be removed from framework.
		Inter-organizational supply chain in networked enterprises	This element is validated and will remain in final practical framework
	Process	Alignment of cross organizational business process	This element is not validated and needs to be removed from framework.
		Supporting distributed business process	This element is validated and will remain in final practical framework
	Service	Model-driven approach	This element is not validated and needs to be removed from framework.
		Cloud standardization projects	This element is not validated and needs to be removed from framework.
		Service oriented architecture	This element is validated and will remain in final practical framework
	Data	Information interoperability	This element is not validated and needs to be removed from framework.
		Platform-independent database abstraction layer	This element is not validated and needs to be removed from framework.
		Data Portability	This element is not validated and needs to be removed from framework.
		Trust model in cross-clouds applications	This element is validated and will remain in final practical framework
Technological	Business	Market Platform	This element is not validated and needs to be removed from framework.
		Aggregator	This element is not validated and needs to be removed from framework.
	Process	Cloud modelling framework and cloud modelling languages	This element is validated and will remain in final practical framework
		Microservices	This element is validated and will remain in final practical framework
	Service	Middleware	This element is validated and will remain in final practical framework
		Service broker	This element is not validated and needs to be removed from framework.

		Service description languages	This element is not validated and needs to be removed from framework.
		Agents for the service description and discovery	This element is not validated and needs to be removed from framework.
		Open libraries	This element is validated and will remain in final practical framework
	Data	Semantic technologies	This element is not validated and needs to be removed from framework.
		Standardized APIs and data models	This element is validated and will remain in final practical framework
		Cloud Data Management Interface(CDMI)	This element is not validated and needs to be removed from framework.
		Security	This element is validated and will remain in final practical framework
Organizational	Business	Provider-centric interoperability and client-centric interoperability	This element is not validated and needs to be removed from framework.
	Process	Cloud Computing standardization Organizations	This element is not validated and needs to be removed from framework.
	Service	Service Level agreement	This element is validated and will remain in final practical framework
	Data	Data liberation	This element is validated and will remain in final practical framework
Additional findings	New element	Cloud licensing model	Input received as part of interview (int_C1).This element requires a follow-up research and needs to be added to the framework in the form of a second design-evaluation loop according to the Design Science research methodology.
	New element	Change management of cloud applications	Input received as part of interview (int_AC2– 1).This element requires a follow-up research and needs to be added to the framework in the form of a second design-evaluation loop according to the Design Science research methodology.
	New element	Governance of interoperable clouds	Input received as part of interview (int_C3)This element requires a follow-up research and needs to be added to the framework in the form of a second design-evaluation loop according to the Design Science research methodology.
	New element	Agility to business	Input received as part of interview (int_AC2 – 1)This element requires a follow-up research and needs to be added to the framework in the form of a second design-evaluation loop according to the Design Science research methodology
	New element	Digital transformation	Input received as part of interview (int_AC2 – 2)This element requires a follow-up research and needs to be added to the framework in the form of a second design-evaluation loop according to the Design Science research methodology

	New element	Competitive edge for business	Input received as part of interview (int_C3)This element requires a follow-up research and needs to be added to the framework in the form of a second design-evaluation loop according to the Design Science research methodology
	New element	Cost-benefit analysis	Input received as part of interview (int_C4)This element requires a follow-up research and needs to be added to the framework in the form of a second design-evaluation loop according to the Design Science research methodology
	New element	Innovation	Input received as part of interview (int_C4)This element requires a follow-up research and needs to be added to the framework in the form of a second design-evaluation loop according to the Design Science research methodology

Appendix N Data Analysis of interviews

SA	Strongly agree
A	Agree
NADA	Neither agree nor disagree
D	Disagree
SD	Strongly disagree

Interoperability dimensions	Interoperability levels	Enabling factors	Consumer				Autonomous complementors - CPE 1		Autonomous complementors - CPE 2	
			C1	C2	C3	C4	AC1 - 1	AC1 - 2	AC2 -1	AC2 - 2
conceptual	Business	Vendor lock-in avoidance	A	A	SA	A	SA	A	SA	A
		Scalability	SA	A	SA	SA	SA	A	SA	A
		Regulations	D	NADA	A	NADA	A	NADA	NADA	NADA
		Inter-organizational supply chain in networked enterprises	D	A	NADA	A	A	NADA	SA	SA
	Process	Alignment of cross organizational business process	D	A	A	NADA	D	NADA	NADA	NADA
		Supporting distributed business process	D	A	A	A	A	A	SA	SA
	Service	Model-driven approach	NADA	SA	NADA	NADA	NADA	SA	A	SA
		Cloud standardization projects	NADA	NADA	A	NADA	NADA	NADA	NADA	NADA
		Service oriented architecture	A	SA	NADA	A	A	A	A	A
	Data	Information interoperability	D	A	D	NADA	A	A	D	D
		Platform-independent database abstraction layer	NADA	A	A	NADA	NADA	NADA	NADA	NADA
		Data Portability	D	NADA	NADA	NADA	NADA	NADA	NADA	NADA
		Trust model in cross-clouds applications	SA	A	SA	SA	SA	A	A	A
Technological	Business	Market Platform	SA	A	NADA	NADA	NADA	NADA	A	NADA
		Aggregator	NADA	NADA	NADA	NADA	NADA	NADA	NADA	NADA
	Process	Cloud modelling framework and cloud modelling languages	NADA	SA	A	NADA	NADA	SA	SA	A

		Microservices	A	NADA	NADA	A	A	A	NADA	SA
	Service	Middleware	SA	A	A	A	A	NADA	A	A
		Service broker	NADA	NADA	NADA	NADA	NADA	NADA	NADA	NADA
		Service description languages	NADA	NADA	NADA	NADA	NADA	NADA	NADA	NADA
		Agents for the service description and discovery	NADA	NADA	NADA	NADA	NADA	A	NADA	NADA
		Open libraries	A	A	A	A	NADA	A	SA	NADA
	Data	Semantic technologies	NADA	NADA	NADA	NADA	NADA	NADA	NADA	NADA
		Standardized APIs and data models	NADA	SA	A	A	A	A	SA	A
		Cloud Data Management Interface(CDMI)	A	NADA	A	NADA	NADA	NADA	NADA	NADA
		Security	SA	A	SA	SA	SA	A	SA	A
Organizational	Business	Provider-centric interoperability and client-centric interoperability	A	A	NADA	NADA	NADA	NADA	A	NADA
	Process	Cloud Computing standardization Organizations	A	A	NADA	NADA	NADA	NADA	NADA	A
	Service	Service Level agreement	SA	A	A	SA	SA	A	SA	A
	Data	Data liberation	A	A	A	NADA	NADA	A	A	NADA

Enabling factors	Consumer				Autonomous complementors - CPE 1		Autonomous complementors - CPE 2		Aggregate					Validation	
	C1	C2	C3	C4	AC1 - 1	AC1 - 2	AC2 -1	AC2 - 2	SA	A	NADA	D	SD	Validated	Non-Validated
Vendor lock-in avoidance	A	A	SA	A	SA	A	SA	A	3	5	0	0	0	8	0
Scalability	SA	A	SA	SA	SA	A	SA	A	4	4	0	0	0	8	0
Regulations	D	NADA	A	NADA	A	NADA	NADA	NADA	0	2	5	1	0	2	6
Inter-organizational supply chain in networked enterprises	D	A	NADA	A	A	NADA	SA	SA	2	3	2	1	0	5	3
Alignment of cross organizational business process	D	A	A	NADA	D	NADA	NADA	NADA	0	2	4	2	0	2	6
Supporting distributed business process	D	A	A	A	A	A	SA	SA	2	5	0	1	0	7	1
Model-driven approach	NADA	SA	NADA	NADA	NADA	SA	A	SA	3	1	4	0	0	4	4
Cloud standardization projects	NADA	NADA	A	NADA	NADA	NADA	NADA	NADA	0	1	7	0	0	1	7
Service oriented architecture	A	SA	NADA	A	A	A	A	A	1	6	1	0	0	7	1
Information interoperability	D	A	D	NADA	A	A	D	D	0	3	1	4	0	3	5
Platform-independent database abstraction layer	NADA	A	A	NADA	NADA	NADA	NADA	NADA	0	2	6	0	0	2	6
Data Portability	D	NADA	NADA	NADA	NADA	NADA	NADA	NADA	0	0	7	1	0	0	8
Trust model in cross-clouds applications	SA	A	SA	SA	SA	A	A	A	4	4	0	0	0	8	0
Market Platform	SA	A	NADA	NADA	NADA	NADA	A	NADA	1	2	5	0	0	3	5
Aggregator	NADA	NADA	NADA	NADA	NADA	NADA	NADA	NADA	0	0	8	0	0	0	8
Cloud modelling framework and cloud modelling languages	NADA	SA	A	NADA	NADA	SA	SA	A	3	2	3	0	0	5	3
Microservices	A	NADA	NADA	A	A	A	NADA	SA	1	4	3	0	0	5	3
Middleware	SA	A	A	A	A	NADA	A	A	1	6	1	0	0	7	1
Service broker	NADA	NADA	NADA	NADA	NADA	NADA	NADA	NADA	0	0	8	0	0	0	8

Service description languages	NADA	NADA	NADA	NADA	NADA	NADA	NADA	NADA		0	0	8	0	0		0	8
Agents for the service description and discovery	NADA	NADA	NADA	NADA	NADA	A	NADA	NADA		0	1	7	0	0		1	7
Open libraries	A	A	A	A	NADA	A	SA	NADA		1	5	2	0	0		6	2
Semantic technologies	NADA	NADA	NADA	NADA	NADA	NADA	NADA	NADA		0	0	8	0	0		0	8
Standardized APIs and data models	NADA	SA	A	A	A	A	SA	A		2	5	1	0	0		7	1
Cloud Data Management Interface(CDMI)	A	NADA	A	NADA	NADA	NADA	NADA	NADA		0	2	6	0	0		2	6
Security	SA	A	SA	SA	SA	A	SA	A		5	3	0	0	0		8	0
Provider-centric interoperability and client-centric interoperability	A	A	NADA	NADA	NADA	NADA	A	NADA		3	0	5	0	0		3	5
Cloud Computing standardization Organizations	A	A	NADA	NADA	NADA	NADA	NADA	A		0	3	5	0	0		3	5
Service Level agreement	SA	A	A	SA	SA	A	SA	A		4	4	0	0	0		8	0
Data liberation	A	A	A	NADA	NADA	A	A	NADA		0	5	3	0	0		5	3