Expertise
and insight
for the future

Ramalingam Chidambaram

Roadmap for Cloud Optimization

Metropolia University of Applied Sciences

Master's Degree

Degree Programme in Business Informatics

Master's Thesis

17 November 2022

Author Title Number of Pages Date	Ramalingam Chidambaram Roadmap for Cloud Optimization 96 pages 17 November 2022
Degree	Master of Business Administration
Degree Programme	Business Informatics
Instructor	Zinaida Grabovskaia, PhL, Senior Lecturer

In the last decade, the Information Technology industry witnessed one of the biggest paradigm shift in the form of *Cloud Computing*. Cloud Computing is what it enables or should be considered a key ingredient in the process of digital transformation for any company. However, the operational costs of Cloud Computing maybe surprisingly high, if Cloud Optimization is not approached correctly, in a carefully planned way. Therefore, before approaching the challenge of controlling the operational costs in the cloud journey, there is a need to develop a clear roadmap for optimization in Cloud Computing. Solving this problem became the objective for this Thesis.

The study follows the multiple case study approach. In this study, three case projects were chosen to be investigated. The thesis researcher has worked in every case project analysed in this thesis as a developer and as an architect, which was one of the criteria when choosing the case projects.

To develop the roadmap, the existing migration paths to cloud, best practices and governance strategies were explored, the current problems faced in cloud were analyzed, and data was collected from different organizations through interviews, questionnaire and their own publications. The analysis results provided an understanding of the current problems faced in cloud optimization, their impact and, backed up with the review of available best practice, has led to developing own proposal of the governance roadmap for cloud optimization.

By adopting the proposed roadmap for cloud optimization via governance, the case company, as well as wider professional community when applying it in similar projects, will benefit from having a greater visibility of the resources and the actual usage, reduce unnecessary cloud costs, boosts cloud utilization, drives innovation and efficiency. Optimization is all about saving costs, gaining more visibility and efficient management of resources. Also, automation of provisioning, monitoring and governance of resources will add to greater savings of development and operational costs. These actions combined, it would have large impact on the effective management of expenditure, security, and innovation in cloud. The outcome of this study is currently being implemented in multiple phases in several projects in the case company.

Keywords	Cloud optimization, cloud computing, operational costs, cloud costs, cloud utilization, cloud governance

Contents

1 Introduction

Digital Transformation is the use of new, fast and frequently changing digital technology to solve problems. It is the current buzzword and almost all the organizations worldwide are spending on digital transformation technologies - hardware, software, and services - which hit $1.3 trillion in 2017, according to IDC.

One of the examples of digital transformation include Cloud Computing. Cloud Computing can be mentioned as the logical first step towards digital transformation. According to Forbes (Forbes, January 2018), 83% of Enterprise Workloads will be in the Cloud by 2020.

Though the technology itself can be traced back to 1960s, what is currently referred as 'Public Cloud Computing' came into existence after Amazon announced a public preview of Elastic Compute Cloud in 2006 and several companies including Microsoft & Google followed suit. Fast track to 2020, most of the organizations utilize some form of cloud computing and the worldwide public cloud services market is predicted to grow 17% in 2020, to a total of $266.4 billion. What started with the Information Technology industry has spanned multiple industries and is a key enabler for Digital Transformation.

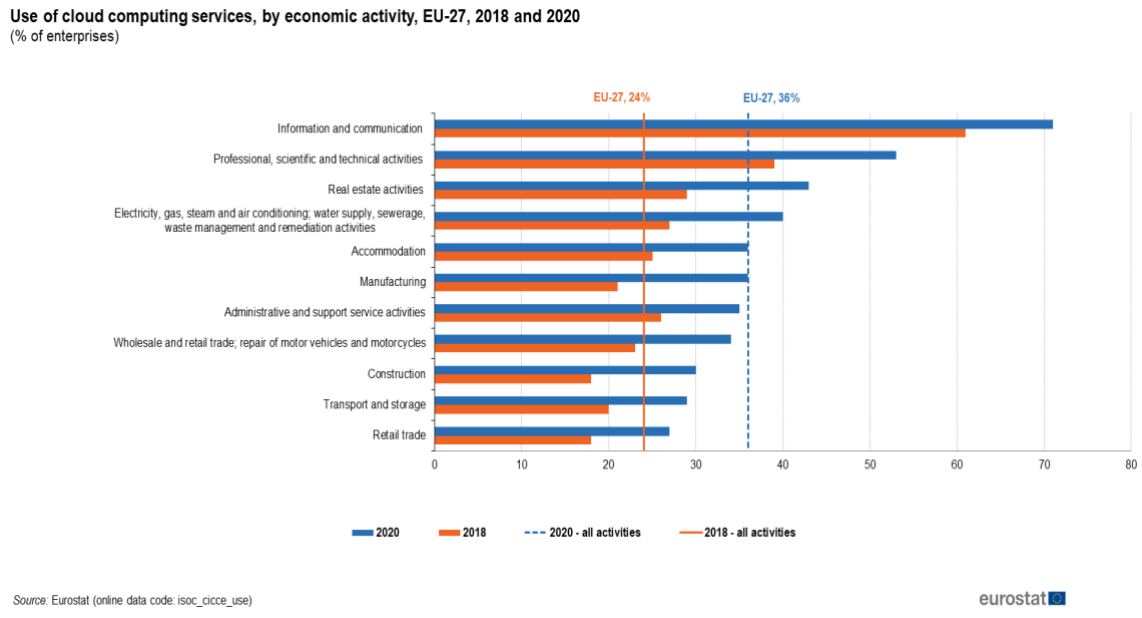


Figure 1. Use of cloud computing services, EU-27, 2018 and 2020 (% of enterprises) (Eurostat 13 January 2021).

Figure 1 shows the growth in usage of cloud computing services across multiple domains in EU. It can be clearly identified that the dependency and usage of the cloud computing services are growing at a rapid rate across all the domains.

Organizations are increasingly adopting Cloud-first strategy and migrating their workloads to cloud. The cloud migration is fueled by Business Agility, Lower costs, flexibility and global scaling. During the early stages of the cloud migration, several companies are concentrating on the speed of the transition rather than the cost, with CEOs considering this as a one-time expense.

Operating a data center in the cloud is always cheaper than on dedicated on-premises servers. But, eventually, when enterprise IT organizations started receiving invoices that are well above the expected costs, the need for cost optimization and governance are getting more importance. In On-Premise environment, infrastructure is financed by fixed upfront investments.

Cloud consumption is an everyday operational expense. Unplanned cloud costs are frequently the result of lack of visibility about the current consumption patterns and past trends, nonstandard deployments, poor organization, and the absence of automated deployment and configuration tools.

Public Cloud services are offered by multiple cloud-service providers with most prominent examples including Microsoft Azure, Amazon AWS, Google Cloud. While every cloud provider has different pricing strategies, they share the common characteristics of cloud computing.

The vast growth of Cloud computing can be attributed to its key characteristics that include Business Agility, Flexibility, Global Scaling, more importantly Zero Capital Investment and pay only for usage. Traditionally setting up datacenters, maintenance and security will always require high amount of capital investments with no or minimal guarantee on the Return of Investments. This is one of the major driving factors in Cloud Adoption. However, the expenditure on the usage of cloud services is still costing companies a lot of budget and without proper control these can be sky-rocketed.

According to Gartner (2019), "*35% of CIOs are decreasing their investment in their infrastructure and data center, while 33% are increasing their investment in cloud services or solutions*." A survey by Opsani (3 December 2019), indicates that Enterprises

are overspending by millions on their cloud bills. The survey was conducted on lead to market of 100 companies with an expenditure of more than $5 million on annual cloud costs. 69 Percent of respondents report regularly overspending on their cloud budget by 25 percent or more, leading to a loss of millions on unnecessary cloud spend.

With the average organization using five clouds, according to the RightScale and Flexera report, finding ways to manage cloud spend and governance is critical. As per Gartner (29 May 2020), *"Through 2024, nearly all legacy applications migrated to public cloud infrastructure as a service (IaaS) will require optimization to become more cost-effective".* These unnecessary spending underlines the need for not only careful planning of resources but also the continuous optimization required when utilizing Cloud computing services.

This thesis will focus on the road to adopt continuous optimization of resources in cloud computing services through effective governance, automation and other techniques to the cloud customers.

1.1 Business Context

The study focuses on establishing a roadmap to continuous optimization of cloud resources in the case organization. The case organization is one of largest multinational telecommunications manufacturer, information technology and consumer electronics company based out of the Scandinavia region. The company has transformed into primarily a network hardware and software provider, committed to innovation and technology leadership, delivering networks across mobile, infrastructure, cloud still adhering to highest standards of integrity and security. The company aims to accelerate the migration of service provider applications to the cloud, drive digital innovation for large enterprise customers, and accelerate transformation and innovation across industries with cloud, Artificial Intelligence (AI) and Internet of Things (IoT). The cloud will also serve as a platform for deploying applications, enabling CSPs to build ecosystem of services that are deployable anywhere.

The case organization uses cloud computing for most of the business processes across multiple business groups including research and development, cloud and network services, network infrastructure and mobile networks. Business Owners are in charge of developing, running the business applications to support IT needs. These individual business units owns the development, control and maintenance of the business

applications running in cloud, although certain services like security and network are shared. IT unit has control over the shared resources and the cost of running business applications are charged back to the respective business units.

1.2 Business Challenge, Objective and Outcome

The overall business challenge for this Thesis is that the company does not have a specified optimization process and there has been little information on the step-by-step instructions to optimize cost spending in cloud. This has been also due to the fact that every project/application is unique. Recently, there has been several initiatives taken to control the costs incurred in the cloud, including multi-cloud strategy that reduces vendor lock-in i.e., reducing vendor dependency and also to reduce the unnecessary cloud spend.

However, a systematic approach is lacking to continuously optimize cloud spending taking into account the different business needs. As discussed in the case organization, this approach is lacking as there is currently no clear roadmap for cloud optimization. Thus, the objective for this Thesis is *developing the roadmap for cloud optimization* becomes. The outcome of the study is *a roadmap for the cloud optimization.*

1.3 Thesis Outline

This study discusses several facets of cloud optimization challenges based on a case study and propose an architecture for addressing those challenges including, establishing effective governance strategy in cloud, automation techniques and other processes.

The scope of the thesis will be limited to the technology companies that has medium to large presence in cloud computing. The thesis aims at identifying the opportunities for establishing a continuous optimization process through effective governance and automation and describe its benefits. The scope of the thesis will also cover the different tools and techniques used for governance, automation and other cost optimization techniques.

The thesis is written in seven sections. The thesis starts with the introduction of the case company and present its business challenges. The next section describes in detail about the research design, approach, how the data collection and analysis will be done. The

third section of the thesis focuses on the current state analysis of multiple projects case study and the fourth section will describe about the relevant existing knowledge and creates the conceptual framework of this thesis. The fifth sections focuses on building the initial roadmap for cloud optimization for the case company. The last two sections contain the validation of the proposal and building a final proposal.

2 Method and Material

This section describes the research approach and the materials used in this thesis. It also introduces the research methods used of the thesis work and the next section presents a research design and the data collection that were used for this study.

2.1 Research Approach

There are various methods doing research. Two broad approaches of data collection and interpretation in research are qualitative and quantitative. In *quantitative* research, larger samples of data are gathered and then statistically analyzed to generalize the results and ensure the reliability of the intervention. *Qualitative* research is aimed at gaining a deep understanding of a specific organization or event. Punch (2014) defined qualitative research as ''*empirical research where data are not in the form of numbers"*. Empirical means that data or research is based on something that is experienced or observed as opposed to being based on theory. Qualitative research uses observations as the data collections methods such as in-depth interview, seeking the perceptions, opinions, beliefs behind people's behavior.

This Thesis uses qualitative research, methods which involves collecting and analyzing non-numerical data to understand the concepts and experiences. The goal is to solve a certain problem by finding answer to concrete questions. For this purpose, the case study approach – one of the most widely used approaches in academia using qualitative research methods (Baskarada, 2014) – is utilized. A Case study involves an in-depth and detailed examination of a particular case or cases. This method is appropriate when the researcher wants to gain concrete, contextual and in-depth knowledge about a subject.

The Thesis follows the multiple case studies research approach to collect information through qualitative process. Cases can be individuals, groups, neighbourhoods, programs and organizations. In this study, a case unit is a project that happened in the past or still ongoing in the case company or other company where the researcher was participant. The researcher has been involved in the actual cases as a developer & designer and in the role of the interviewer with all the respondents from the case organization. This experience has allowed for qualitative inquiry and helped generating

useful insights from the respondents. The key takeaways from these multiple case-studies were recorded and document, and analyzed into a final case study in this Thesis.

2.2 Research Design

To develop the roadmap, the existing practices were explored, the current problems faced in cloud analyzed. The data was collected from different organizations through interviews, questionnaire and also their internal publications. The data analysis provided an understanding of the current problems faced in cloud optimization, their impact and has led to formulating own proposal of the governance roadmap for cloud optimization.

The research design of this study is shown in Figure 2 below.

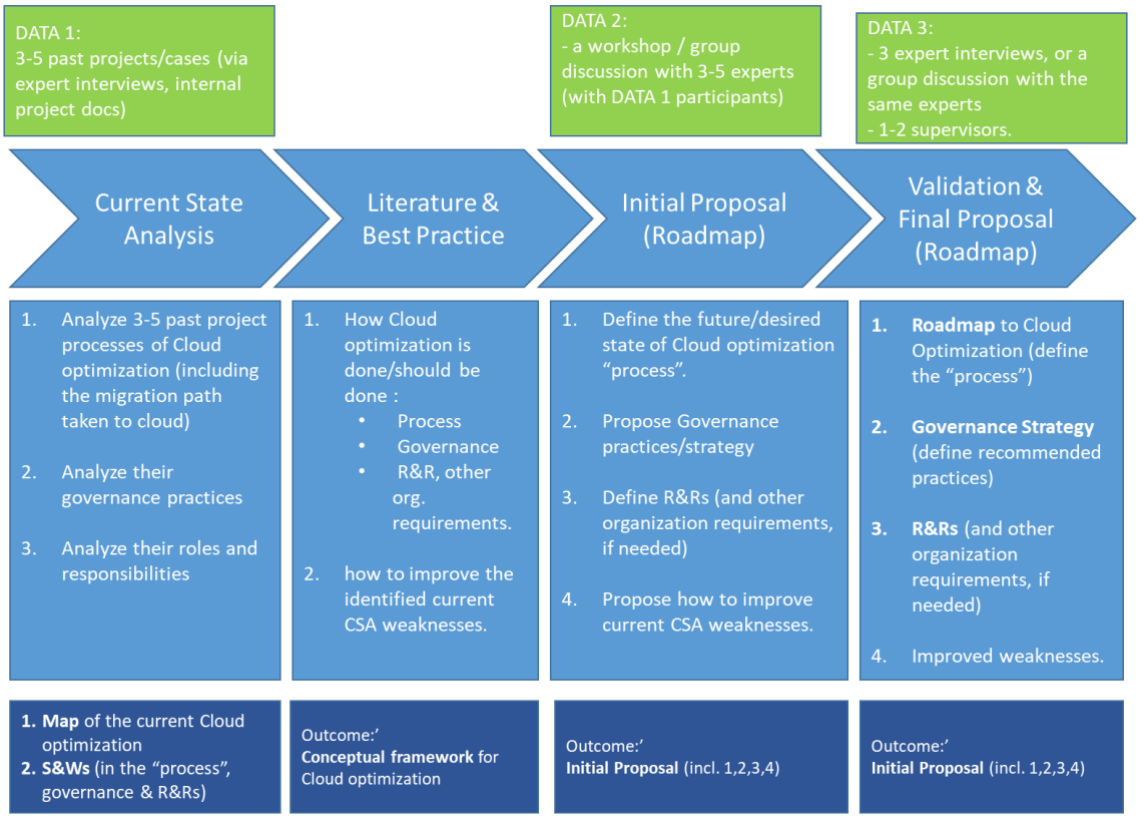


Figure 2. Research design of this study.

2.3 Data Collection and Analysis

This study draws from a variety of data sources, and the date was collected in several data collection rounds. Table 1 shows details of Data collections 1-3 used in this study.

In this study, three case projects were chosen to be investigated. The researcher has worked in every case project as a developer and as an architect, which was one of the criteria when choosing the case projects. The chosen projects were also similar in the design, technology used and share other characteristics too, without any attachments to other projects.

Table 1. Details of Data collections 1-3 used in this study.

	Participants / role	Data type	Topic, description	Date, length	Documented as
	Data 1, for the Current state analysis (Section 3 or 4)				
1	Respondent 1: Capability Manager, Experience > 10 years, Case A	Telephonic Interview	Cloud Migration Approach, Optimization, Cloud Center of Excellence, Monitoring, Continuous Integration, Continuous Deployment, Compute Reservation, Sharing common pool resources	Jun 2021, 35 mins	Field notes
2	Respondent 2: Cloud Architect, Experience > 10 years, Case B	Telephonic Interview	Cloud Migration Approach, Continuous Optimization, Cloud Center of Excellence, Operations, Continuous Integration, Continuous Deployment	Mar 13 2021, 50 mins	Field notes
3	Respondent 3: Self, Experience > 12 years, Case C	Documentation, Own experience	Cloud Migration Approach		Internal documentation
	Data 2, for Proposal building (Section 5)				
4	Respondent 1: Capability Manager, Experience > 10 years, Case A	Telephonic Interview	Cloud Migration Approach, Optimization, Cloud Center of Excellence, Monitoring, Continuous Integration, Continuous Deployment, Compute Reservation, Sharing common pool resources	June 2022, 40 mins	Field notes
5	Respondent 2: Cloud Architect, Experience > 10 years, Case B	Telephonic Interview	Cloud Migration Approach, Continuous Optimization, Cloud Center of Excellence, Operations, Continuous Integration, Continuous Deployment	July 2022, 30 mins	Field notes
6	Respondent 3: Self, Experience > 12 years, Case C	Documentation, Own experience	Cost Optimization in Cloud, Invoicing, Enterprise Agreement Challenges, Automation, Cost Reporting	July 2022, 40 mins	Internal documentation, Discussion

					with Managers, FinOps Team, Operations Team
	Data 3, from Validation (Section 6)				
7	Respondent 1: Consultant Experience > 10 years, Case A	Meeting	Optimization, Cloud Center of Excellence, Monitoring, Continuous Integration, Continuous Deployment	Oct 2022, 30 mins	Field notes
8	Respondent 2: External Consultant, Experience > 10 years, Case B	Telephonic Interview	Cloud Migration Approach, Continuous Optimization, Cloud Center of Excellence, Operations, Continuous Integration, Continuous Deployment	Nov 2022, 30 mins	Field notes
9	Respondent 3: Self, Experience > 12 years, Case C	Own experience	Cost Optimization in Cloud, Invoicing, Enterprise Agreement Challenges, Automation, Cost Reporting	Oct 2022, 30 mins	Discussion with Managers, FinOps Team, Operations Team

As seen from Table 1, Data 1 was gathered and analyzed in the current state analysis phase. The primary data consisted of personal interviews, discussion with internal team members, documentation analysis and participant observations as the thesis researcher was a member of the project teams in all the analyzed projects.

The aim of the interviews was to identify the current state of continuous optimization, challenges in cloud migration; the current process of monitoring the resources in cloud; usage of Continuous Integration(CI) and Continuous Deployment (CD) tools/process; introduction to Cloud Center of Excellence (CCoE), and the challenging areas which needs improved process management.

For the interviews, the most knowledgeable stakeholders were selected from each project with the expertise in cloud optimization and its governance. The interviews were conducted as semi-structured, telephonic interviews, with questions created in advance. In the interviews, the field notes were taken. The questions for interviews can be found in the appendices.

The textual data was analyzed using Thematic/ content analysis.

3 Current State Analysis of Cloud Migration, Governance and Optimization Process Based on Three Projects

This section presents the analysis of the current state of the cloud migration, governance and optimization process in the case organization, done on the example of three recent cloud migration projects. Section 3.1 explains the goal of the current state analysis, the systematic approach taken to collect data, and the expected outcome from the data collection. Section 3.2 focuses on analysis of three recent cloud migration projects and their design, governance and cost optimization processes. Section 3.3 summarizes the findings from the analysis of the three case projects focusing of the current state of their optimization and governance processes.

3.1 Overview of the Current State Analysis

The goal of the current state analysis was to identify the major stages and features of the cloud migration projects, the paths taken for migration in these projects i.e., IaaS, PaaS, SaaS, the decisions behind these choices, the current Cost Optimization processes, the existing governance practices followed in these projects, the roles and responsibilities of multiple players who were part of the projects, and come up with the lessons learnt from them.

For this purpose, the current state analysis focused on analyzing three projects related to cloud migration projects. The sizes of these project can be categorized as medium and large (M & L) depending on the team size, as well as the estimated duration for completion the project, users served and the number of applications that are either created or migrated. These categorization of projects was important to understand the difference in the level of controls by the design architects, developers, project managers and other project members, stakeholders in the projects and the influence of organization decisions.

Although the data collection included such details as the paths taken for migration, driving factors for going cloud, chosen technologies and the influence of organizational/corporate decisions, the true focus was on collecting the details on (1) *the optimization processes* that were used during the different phases of the project and (2) the current state of *continuous optimization of cloud resources*. Enquiry on the governance practices that were established or followed, roles and responsibilities of different stakeholders in the project were also part of the data collection.

Data collection in the case projects involved interviewing/discussion with the experts (i.e. project team members) who were part of the projects. The interviews were based on a questionnaire prepared in advance to focus on understanding how the project was implemented, its driving factors, stages, roles and responsibilities, and mainly its cost optimization processes and governance practices in continuous optimization of cloud resources.

The current state analysis of these case projects ends with identifying the strengths and weaknesses in the current processes related to cloud migration and continuous optimization of cloud resources. It also provided the map of the current cloud optimization process in each case project and, based on the above, the overall lessons learnt.

3.2 Multiple Case Project Analysis

Currently, in the case organization the projects utilize the agile software development methodology for most of the projects. These practices involve discovering requirements and developing solutions by self-organizing and cross-functional teams.

The complexity of the three projects for the case-study can be categorized on two levels: One and Two, where Level 1 is very complicated and large project, while Level 2 can be rated as medium level. Categorizing the complexity helps to define the needed resources for the project. Multiple sprints are then required to complete a full-fledged product or solution. Also, depending on the project the team size may vary and there may not be even the minimum team required for a sprint, so the scrum agile methodology might not be strictly followed. This can happen because of the funding for the project, changing organizational strategy or management etc. Typically, the discussion and guidance on the tooling that will be used for the project is heavily influenced by the organization’s policy and the vendors chosen.

Below, the analysis focuses on the cloud optimization processes of the three case projects by analyzing the project practices and interviewing the team members (Cloud Architects, Lead Developers) of these projects, who are involved & participated in these projects.

3.2.1 Case Project A

The project describes the Cloud Analytics Transformation journey in another case company. The objective was a Business Intelligence solution development that comprises of two sets 1) new capabilities e.g., for marketing and customer support 2) migration of existing on-prem capabilities for finance and sales. The organization was a new startup and had adopted the policy of developing solutions only in cloud to reduce the large capital investments, flexibility and ability to quickly develop the solutions. The case also includes other systems that was migrated to the cloud platform which support the Analytics Transformation but doesn't discuss these in detail as the developers involved in the interviews did not directly worked with these transformations (can be considered as source system migrations).

The Project Context:

The case company founded at the beginning of year 2016, is a mobile manufacturing company based in the European region selling both feature and smart-phones. The case company had purchased the feature phone mobile business unit from a large technology company, along with another company which is a subsidiary of an electronics manufacturer. The case company would be responsible for the selling of the devices while the actual manufacturing will be done by the manufacturing partner. The case company had quickly grown to be recognized as one of the leading seller of both feature and smart phones around the world. The case company aims to make mobile technology accessible to all with the devices that can be trusted.

Like other smaller organizations, the case company started with a smaller team and had quickly grown to be recognized as a market leader. Today the company is operating from more than 50 locations worldwide. The case company from the beginning had focused on the digitalization process and didn't want to invest on the on-premise data centers setup, fully developing solutions only on the cloud platforms. Although there were multiple business units, the license for development of solutions on cloud was controlled to some extent by the whole program.

The case company had received large infrastructure on-premises data centers as part of the purchasing deal with the large technology company. The large technology company which had multiple businesses ran several solutions in the on-premise data centers supporting the mobile business. The case company had to get rid of the

unwanted solutions in the data center, migrate the needed solutions to the cloud platform and shutdown the on-premise data centers which were generating higher costs. This project of setting up the Analytics platform on cloud was to support the new capabilities for marketing and sales department and to migrate the existing finance reporting on the on-premise systems. This interview was held with the person who was the BI developer at the time of setting up the Platform and continuing as a Lead Developer/Capability Manager till date. The project had started around first quarter of the year 2016. The researcher (interviewer) too has one year experience as an Infrastructure Lead/Specialist in setting up an Application Integration platform on the cloud for the case company. The researcher also had contributed to several proposals on improving the Automations and adopting the DevOps culture for the case organization.

The Project Stakeholders:

The project aims to provide the reporting of data by developing new capabilities for the marketing and customer support teams, and continue supporting the finance and sales team with the existing data, needs to be migrated to cloud as early as possible. The stakeholders included business teams from Sales, Finance departments. The new capabilities were driven by both the marketing and the customer support teams. Later on, the official project stakeholders included:

Table 2. Project A´s stakeholders.

Who	*Role with respect to the project*
Business Users (Key Businesspeople, Business Controllers, Finance department)	End Users of the projects, users of the Business Intelligence reports.
Business Users (Marketing and Sales departments	End Users of the projects, users of the Business Intelligence reports.
Customer Development Team	Developers of the business reports from the customer end
Source systems Owners	Business owners of the source system who provide the access to the source data to be extracted, transformed and loaded into the data warehouse

The Project Goals:

The target was to have a Cloud based Business Analytics platform supporting the business reporting needs of multiple departments that includes, sales and marketing, finance etc. As part of the deal on the feature phone business, the case company has received over scaled and unsuitable BI applications located in on-premise data center. New & modern cloud solution was needed to support the date capture and processing of device telemetry too. The challenges faced by the company are (1) The timeline was aggressive (the target was to have the BI platform ready in 7 months), in the midst of new ways of working with the manufacturing partner, (2) Majority of data sources systems were also undergoing migration from on-premise to cloud that includes ERP, sales systems, repair systems etc., (3) The Major Challenge was to support the ongoing business but also scale-up new capabilities to support new portfolio in parallel.

Cloud platform was chosen because of the organization strategy to adopt digitalization, reduce the dependency on large data centers, less capital required to setup the infrastructure including data warehouse and other technical solutions and license costs. The platform included tools for extracting the data from multiple source systems, loading the data into a data warehouse, databases and report creation in a visualization tool all of which are needed to be setup in the cloud with no dependency on the on-premise.

The cloud-based Analytics platform was a new development project for the company which had just started, and the platform should enable solution/report development for the new capabilities, successful migration of few existing solutions in the on-premise systems. Once the platform has been established, the company had to ramp down the legacy systems located in the large data centers.

Stages in the Project:

Step 1. Cloud Assessment phase – The case company had received over scaled legacy on-premises systems that ran multiple solutions. Assessment was done on the systems and the aim was to identify the solutions that needs to be migrated to the cloud platform. The assessment not only included the analytics solutions but also considered all other systems that supported or feed data to the analytics platform and supporting other businesses.

Step 2. Planning and Kick-off - The project's objective was to get all the Business Intelligence capabilities in cloud i.e., migrating the existing solutions from on-premise to cloud which will lead to the release of these legacy costlier assets. For the analytics platform setup, Re-factoring approach was chosen. The main reason for choosing this approach is because of the main decision of the organization to adopt Platform-as-a-Service approach. Microsoft Azure was chosen as the vendor or the cloud service provider.

A Main System Integrator (external third-party Consulting Company) was chosen to start the work and also to evaluate the best suitable platform. The project team contained design experts from the system integrator and also a mix of both internal company members & subject matter experts (SMEs) from other external companies. The development and SME teams were located in Finland, Poland and India.

Other source systems of the analytics platform were mainly choosing the refactoring approach or re-platform approach. This will not be discussed in detail here in the context of analytics transformation journey. Figure 3 shows the stages in Project A.

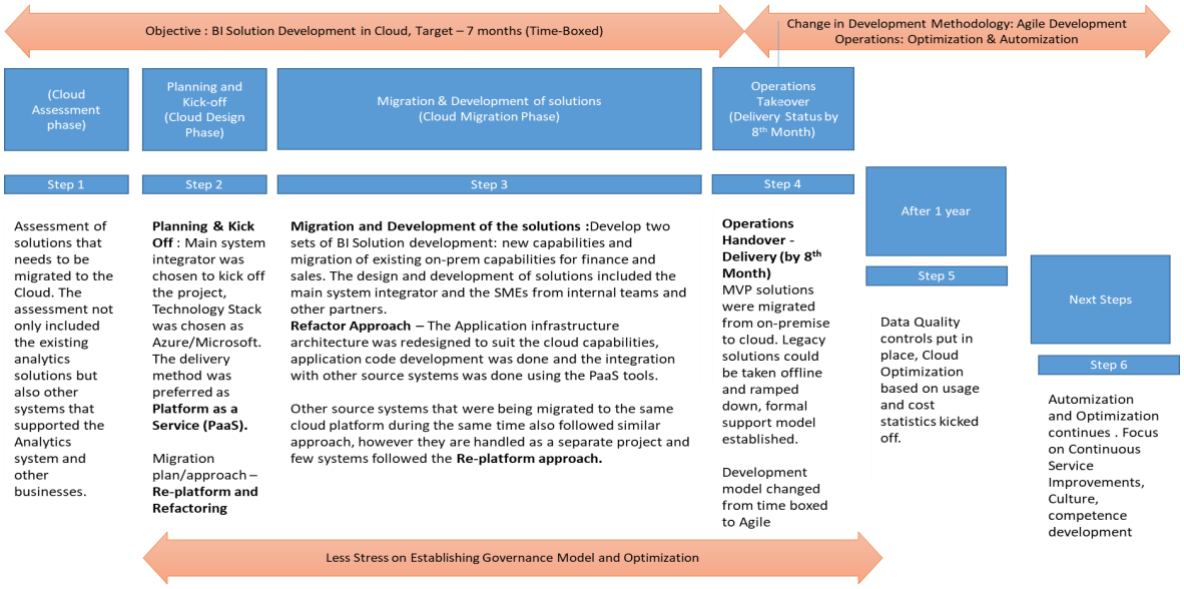


Figure 3. Project A, stages in the project.

Step 3. Migration and Development of the solution - The main focus was to develop all the capabilities in cloud and to establish a formal support model. This included redesigning the application/infrastructure architecture, Application Code development and the integration with other source systems. Tasks involved in the project were migration of existing solutions, developing new capabilities, testing and go-live routines.

Although during this phase, there were not clear accountabilities and the goals are not clearly established, this was solved as the project evolved and strong coordination between the multiple teams including the main system integrator, source teams and the SMEs enabled them to quickly develop or migrate solutions. Other source systems were also performing migrations during the same period but was handled as a separate project.

Step 4. Operation Handover - The project achieved some of the major milestones by the eighth month that include ramping down of legacy BI applications and platforms in the on-premise. Finance and Sales MVP solutions were migrated from on-premise to cloud. A formal support model was established for the analytics solution. MVP reports for different systems were already in production and the new source systems were also operating in cloud. The project development model was then changed from time-boxed to agile.

Step 5. The project introduced different development streams that includes consumer, operations, finance and platform, development of advanced analytics by using Data science in few areas and some basic ITIL processes and IT Controls were put in place. Few optimization techniques for cloud platform scaling based on usage and cost statistics were also introduced.

Step 6. Current Status – Focus was set on Continuous Service Improvements, Automations plans were started and further optimization of cost and performance of the system are planned. Also, there are few initiatives introduced that aimed to improve the competence in the cloud platform and the culture of the team.

Problems:

The main problems for the project started with having a fixed deadline and the lapse would involve huge costs in managing, monitoring and ramping down the over-scaled legacy resources in on-premise data centers. The application team was managing the application and solutions in a different technology stack in the on-premise environments and migrating to cloud would mean a very high learning curve and change of technologies, experimenting the setup, and training the operations team too. The application team needs to support the on-going business with legacy setup, as well developing/migrating the solution to cloud. This also resulted in lesser focus on the

automation in cloud and the modification of continuous optimization techniques used in on-premise environment to be applied effectively on cloud.

The Project Strength & Weakness in terms of Cloud Optimization process:

Table 3. Project A, strengths and weaknesses in terms of cloud optimization.

Positive	**Negative**
Decision to choose cloud as the company's development platform and particularly preferring the Platform-as-a-Service model	No Piloting of the solution, Multiple source systems was undergoing changes at the same time but there was little coordination between these teams and no best practices shared. Objective was to get all these systems up and running in cloud.
Knowledge gained – The development teams were had a high learning curve and trainings which can be set up as a base for future developments and trainings	Governance and Automation was considered not in the design and planning, No CI/CD pipelines till date, DevOps culture
The Development Team was continuing with the Optimization as part of the enhancements after the closure of the actual project	Team knowledge on skills and legacy knowledge, lack of Centralized Cloud Advisory board or Cloud Center of Excellence
Cost Optimization initiatives, Support Model – Special attention was given for the cost optimization initiatives as soon as it was realized that the main agenda for going cloud is not only for ease of developments & no capital costs but also to reduce operational costs	Focus on the Cost Optimization Initiatives – although there were some initiatives on the Cost optimization drives no concrete focus and development meant there is less achieved till date.
Ramping down of legacy systems, on time migration of all the solutions to the cloud	Centralized Team exists but didn't had any documented best practices and guidance for the project.
Main system integrator's knowledge on the cloud systems meant faster development of solutions on the cloud whereas the support provided by SMEs ensured all the solutions working as expected	Foundations needs to be planned well like the data (common hierarchies, master data codes, etc.) and for Azure (IAM, resources, networks, etc.)

The project had chosen a single cloud vendor with the pay-as-you-go option. Main system integrator along with other SMEs were able to achieve the pilot and MVP solutions and migrate all the on-prem solutions to Cloud, close to the deadline as this

enabled them to phase out or ramp down the legacy assets, which required high maintenance and support costs. The project emphasized on the usage of Platform as a Service (PaaS) services and Infra as a Service was used only when necessary. Optimizing cloud platform scaling based on usage and cost statistics was started soon after the successful migration and development of MVP solutions.

As per the interviews, there was little experience amongst the teams for migrating or developing the solutions. Though the implementation could've used different solutions for integrating data or modelling, access etc., the safest option was chosen. As stated by Respondent 1:

> "*The resource planning was very challenging in the early phase of the project as the key personnel including SMEs had to work in multiple projects."*

While there were few initiatives taken to optimize cloud platform scaling costs, there was no concrete actions during the initial period and the changes or recommendations were introduced during a later stage. Change in data warehouse and ETL technologies due to the migration and cost factor also played a major challenge for the development teams. High importance and focus was on developing and migrating the solutions from on-premise to cloud while other factors like realizing cost optimization, governance, building knowledge base, best practices were not given the same level of focus. Although the best practices of integrating and developing solutions in cloud was considered, the timeline was critical to experiment multiple solutions or alter the solution design.

The Project Current Status (as of now):

Even in the current situation, most of the monitoring of the system was done manually. Continuous Integration and Continuous deployment (CI/CD) pipelines are not used to its full extent. DevOps culture is not adopted and the actual teams needs more training on understanding and adopting DevOps. Few automations such as pausing a Data warehouse or stopping compute when not in use have been developed and are in use, but other automation capabilities are still on-going. It can also be due to the fact that, some of the components like data warehouse still not support fully continuous deployment pipelines. There is also visible lack of management support for upgrading to the latest technologies. This can be also because of the little understanding of how the change could yield benefits and what the impact is.

This project like most other cloud projects didn't focus on building the governance and cost optimization processes during the design or implementation phase and this was considered only after the go-live was completed. As per the interviews, although there is some focus on the DevOps culture, even after several years of analysis it is still not implemented successfully and completely.

3.2.2 Case Project B

The project aims to establish a Cloud based Business Intelligence (BI) and Analytics platform. The objective was to provide an easy and synchronized access to relevant business information to support fast and fact-based business decision making to improve revenue growth and optimization, controlling costs and measuring business performance. For the purpose of faster deployment, scaling and less capital investments the project mainly chose the Cloud platform for the Business Intelligence and Analytics solution setup. This also aligned with the Company's mission of reducing the dependency on large data centers and migrating workloads to Cloud.

The Project Context:

The case organization is one of largest multinational telecommunications manufacturer, information technology and consumer electronics company based out of the European region. The company has transformed into primarily a network hardware and software provider, committed to innovation and technology leadership, delivering networks across mobile, infrastructure, cloud still adhering to highest standards of integrity and security. The company aims to accelerate the migration of service provider applications to the cloud, drive digital innovation for large enterprise customers, and accelerate transformation and innovation across industries with cloud, Artificial Intelligence (AI) and Internet of Things (IoT).

The case organization uses cloud computing for most of the business processes across multiple business groups including research and development, cloud and network services, network infrastructure and mobile networks. Business Owners are in charge of developing, running the business applications to support IT needs. These individual business units owns the development, control and maintenance of the business applications running in cloud, although certain services like security and network are shared. IT unit has control over the shared resources and the cost of running business applications are charged back to the respective business units.

The business unit in context deals with the licensing and patenting data for the organization. The organization lends out licenses and patents to multiple companies around the world and generates revenue on the same. The need for a Business Intelligence report/platform arose as most of the reports handling this data was generated manually using excel and other tools that enabled collecting the data from different source systems were more complex. This interview was held with the person who was the BI Platform and Cloud developer at the time of setting up the Platform and continued as a Lead Developer/Cloud Architect after the closure of the actual project. The project had started around first quarter of the year 2017. The researcher (interviewer) too have one year experience as an Automation/Operations specialist working in the project improving the operations area. The researcher also contributed to adopting the DevOps culture in the project.

The Project Goals:

The project aimed to establish a Cloud based Business Intelligence (BI) and Analytics solution. Also, the BI and Analytics platform will provide a solution to the businesses to analyze and follow business performance indicators that enables data-driven decision making, improve ways of working and information sharing. The client acknowledged the need for creating a business intelligence report/platform that can combine data from multiple source systems, create a model and facilitating report creation on business performance indicators that support decision making. Previously, part of these activities were handled manually and using different tools.

The client created a project team for building this solution and had specified the requirements which mainly includes to establish the platform on Cloud. The BI platform should source data from both internal and external data sources built on SAP Business By-Design (ByD), P20, Salesforce and Cloud-based IP management system. The objective was to provide the BI report/dashboard on PowerBI for the business users, with the underlying data model created in the Enterprise Data Warehouse. Enterprise Architect who was the part of the team during the design phase created the solution architecture for the platform/solution in cloud.

Cloud platform was chosen because of the organization strategy to adopt digitalization, reduce the dependency on large data centers, few source systems are already on cloud, less capital required to setup the infrastructure including data warehouse and other technical solutions and license costs. The platform included tools for extracting the data

from multiple source systems, loading the data into a data warehouse, databases and report creation in a visualization tool all of which are needed to be setup in the cloud with no dependency on the on-premise.

The Project Stakeholders:

The project's need was discovered by the key stakeholders i.e., the business and a team was formed for the execution of the project. The initial team consisted of Product Owner and the Enterprise BI Architect. Later on, the official project stakeholders included:

Table 4. Project B´s stakeholders.

Who	*Role with respect to the project*
Business Customers	Customers/End Users of the projects, also the demand for the new tool is raised by them
Business Owner	Project Sponsor, providing the overall business direction, gathering requirements from business and prioritizing items
Scrum Master	Managing the scrum team, coaching the team on scrum practices
Development Team	Project/Solution development team consisting of different technical experts from multiple service providers
Enterprise BI Solution Architect	Architecting the whole Business Intelligence solution
Microsoft Azure	Cloud Infrastructure and product software provider

The team of developers was consisting of experts in different technologies of BI, including Data Modeler, Database developer, Cloud Expert, Report Developer and a Scrum Master. Most of the tooling was already decided by the enterprise architect and an estimated timeline was shared with the development team (scrum team) for the delivery.

Stages in the Project:

The Business department was handling the organization's licensing data and discovered a need for an Analytics solution/platform to enable data-driven fast decision making and to improve the current ways of working. Also, the business stressed on creating the platform on cloud to reduce the dependency on data centers, faster deployment, scaling and reduced capital investments. The project need was discovered by the key stakeholders i.e., the business users and a team were formed for the execution of the

project. The initial Project team during the assessment and design phase consisted of Product Owner and the Enterprise BI Architect. Figure 4 shows stages in Project B.

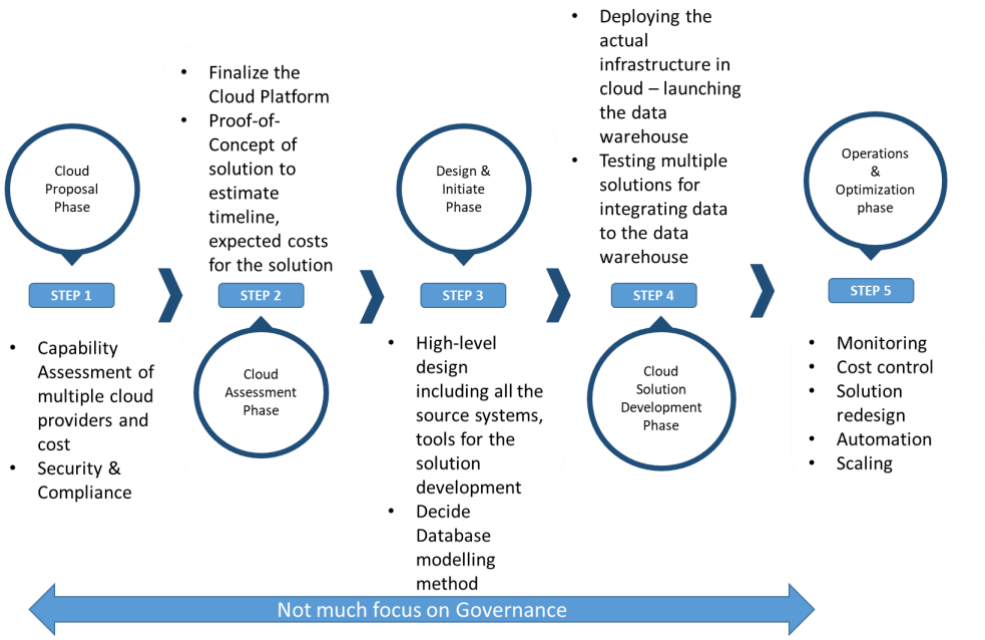


Figure 4. Project B, stages in the project.

As seen from Figure 4, Project B was comprised of the following stages:

Step 1. Since it was decided that the platform/solution would be hosted on a cloud platform, the team wanted to analyze the cloud platform capabilities. Leading cloud providers was invited for a demo of their cloud capabilities. Little information is known how the demo was conducted and what level of analysis on the demo was conducted as this is mainly done by the internal company employees including the business persons & stakeholders and not the project team. Business owner for the project might have been part of this exercise.

Step 2. The project team was formed which consisted of the Product Owner and the first team member was the Enterprise BI Architect. The role of the BI Architect was to create a high-level BI architecture in the cloud platform. After the initial demo in the assessment phase, Microsoft Azure was chosen as the cloud provider for implementing the solution. Also, Microsoft Azure was requested for conducting a proof-of-concept or a pilot solution mainly to estimate the timelines, cost and tools/capabilities of the Azure cloud platform in detail. Apart from this, other activities included in this phase are Request for Proposal invitations from multiple consultancy companies for the development, delivery and

operations of the platform on cloud. The project owner had analyzed the proposal from multiple companies for carrying out these tasks related to development of the project.

Step 3. During the Design phase, a high level BI Architecture was created which included all the source systems that are to be integrated to the BI platform on cloud and the main technical solution/tools was also selected including the Microsoft Azure Data Warehouse. The Database modelling method was also decided by the Enterprise BI Solution architect. Other activities included choosing multiple external vendor to develop the solution based on the architecture. The actual start date for the development team along with the estimated timeline and the expertise needed for the development was communicated. The project owner also did interview few experts from the consulting company for the different technical roles. This includes experts in different technologies of BI, including Data Modeler, Database developer, Cloud Expert, Report Developer and a Scrum Master.

Step 4. The development team started working on the implementation based out of the design. During this implementation phase of the project, is when the developers discovered the actual challenges of integrating or collecting data from the different source systems. This prompted to change in the timelines & estimates of the actual delivery of the BI solution. The Enterprise Architect had already created the design and explained it to the development team. Most of the tooling was already decided by the enterprise architect and an estimated timeline was shared with the development team (scrum team) for the delivery. This estimate was based on the proof-of-concept solution conducted by the Azure cloud provider, which did not consider the challenges in integrating the source systems. The development team had to test out multiple solutions in the cloud which included tools on Platform as a solution (PaaS) and Infrastructure as a Solution (IaaS) models for extracting the data from the source systems to cloud, storing it in a staging area, loading it to the data warehouse, creating the database modelling, creating databases for preparing the presentation layer for easy retrieval by the reporting systems. The final solution was a mix of both Infra-as-a-Service, Platform-as-a-Service tools.

Step 5. After the development phase, the development team successfully handed over the platform to the operations team but continued with the solution/report development and doing other enhancements on the project. The Team also identified potential cost saving opportunities by changing the different mix of solutions/tools used in the project. Automation including CI/CD was also introduced to improve the deployment process.

Automated monitoring solutions were built after receiving feedback from the business customers on the platform downtime. Most of the infra-as-a-service components that included Virtual Machines were replaced by Platform-as-a-Services tools during the Optimization phase of the solution.

Problems:

According to the interviews, the development team was not part of the initial phases including design and the Enterprise BI Solution Architect had little experience on the Cloud platforms. The design and the tools available for integration with source systems are didn't allow wide variety of tools to be used. There are also limitations with the PaaS offerings, which prompted to use the solutions/components for integrating based on the IaaS model. For example, Datafactory V1 was not suited for most of the transformation logic and the solution was to have a SQL Server Integration Services (SSIS) based on Virtual Machines which is as IaaS solution. The development team also had little experience on the cloud platforms and not completely aware or had previously tested multiple solutions in the cloud. This created problems in the development phase adding to the challenges of integration with the multiple source systems.

During the Cloud Assessment phase, the pilot or proof-of-concept solution didn't include integrating with the actual source systems and relied mainly on the source data in an excel transferred from a laptop to a service (Storage Account) in the cloud itself, while the actual source systems are outside of the cloud platform. The PoC study did not include any of the actual system that needs to be integrated, instead it was just assessing the capabilities of the vendor.

During the design and development phase, the main goal was to get the solution/platform running on the cloud rather than optimizing costs, as there was little awareness on the forecasted cost of the resources when running for a longer periods. The project included many technical solutions that were not tested before. While the architecture included connecting to multiple source systems, these integrations were not tested during the Proof-of-Concept (PoC) study.

The project was one of the first projects to be established in the cloud. There was no central Cloud Team or IT Team at the time of this project development. This also meant there were no or little guidance on best practices. The project was a high learning curve for the project team as cloud development was relatively new and constantly changing.

These learning and lessons learnt was then served in framing the best practices and the experience was shared with other teams. Cloud adoption was also relatively less during the time of the project implementation, which meant there were more solutions which were under development or in the preview phases only.

The Project Strength & Weakness in terms of Cloud Optimization process:

This project was one of the first projects to be established in the cloud. A proof-of-concept study was conducted and the capabilities of the cloud providers was evaluated before the initiation of the project. The project was given high importance and all the needed help and support was provided by the management. The source systems also coordinated with the project development team and helped them experimenting and integrating the solutions. The revised estimates i.e., the changes in the timelines were accepted and more support was provided by the Management and the developers were able to experiment with the tools and solutions before actual implementation. The project was a high learning curve for the project team as cloud development was relatively new and practices were constantly changing. These learning and lessons learnt can serve in framing the best practices and the experience to share with other teams.

Table 5. Project B, strengths and weaknesses in terms of cloud optimization.

Positive	**Negative**
Decision to choose Cloud platform for the development of the BI Platform/solution	The design and the tools integration of actual source systems was not optimized for Cloud or didn't consider in depth about the various implementations of the cloud
Capability assessment of multiple cloud providers, security & compliance	Governance and Automation was considered not in the design phase as the main objective was to get the solution/platform up and running
Decision to build Proof-of-Concept solution to assess timeline, cost and capabilities	Limited guidance on the solution, best-practices (only vendor provided)
Ability to pilot test multiple solutions before finalizing the solution during the development process	The development team and the enterprise architect was having little experience on the cloud platforms

Learning Curve – learning about the cloud technologies and various options for implementation of the solution	Pilot or proof-of-concept didn't reflect the actual design of the project. It was again a demo on the capabilities.
The Development Team was continuing with the Optimization as part of the enhancements after the closure of the actual project	Little awareness on cost forecasting of the resources in the cloud
	No centralized IT Team meant the organization didn't had any documented best practices and guidance for the project.

The project had used the resources and other best practices made available only by the cloud service provider and must use mix of different deployment models, including IaaS and PaaS services. More stress was on getting the solution working rather than utilizing the full functionality of cloud. Although the best practices of integrating and developing solutions in cloud was considered, the timeline was critical to experiment multiple solutions or alter the solution design. Automations including CI/CD capabilities were not part of the initial project completion and several activities were following the manual approach. These automations were put in place or even considered only during the operational phase of the project.

The Project Current Status (as of now):

This project like most other cloud projects did not focus on building the governance and cost optimization processes during the design or implementation phase and this was considered only after the go-live was completed. DevOps culture introduced later during the Operational phase, also guided in the automation of processes and certain deployments. Continuous Integration including version control and testing was followed wherever it was possible and applicable, although it is not completely automated or optimized yet. In the past, most of the monitoring of the system was done manually and over the years few automated monitoring capabilities were developed but this is on-going, and all the use-cases are not completely automated yet. It can also be since, some of the components like data warehouse still not support fully continuous deployment pipelines. As stated by the Cloud Architect:

> "*Cloud is a growing and fast changing area, where new methods and tooling capabilities are release almost every month*".

Several of the solutions that were put together during the implementation phase had undergone changes after the completion of the project and more cloud native approach/tools were used.

3.2.3 Case Project C

The project/program describes the migration and transformation journey of multiple applications to cloud in the case company.

The Project Context:

The case organization for both the project B and C are the same, however the business units differ.

The business unit in Project C offers platform services that includes setting up the platform, all necessary infrastructure, firewall, security, and governance in cloud and does the migration of the applications along with the Application Development or Support Teams. As part of the program/project, the centralized platform team manages the underlying cloud platform, security, and governance of all the applications running in the cloud. The project/program will be conducted as and when the individual application teams are ready for migration of their application. The plan was to complete the migration before end of 2022, but this might change due to several reasons including the impact on funding due to COVID-19. The researcher (interviewer) has been working with the central platform team as Solutions Architect and developing the best practices on migration, security, and governance for the overall cloud platform.

The Project Goals:

The objective was to migrate several applications hosted both in on-premises to cloud and applications in cloud that was migrated to Brownfield earlier should be migrated to Greenfield. In the past, some of the applications had migrated to cloud (mainly rehosted i.e., lift and shift) and are categorized as brownfield. Brownfield applications do not use the full potential of cloud and are just residing in the virtual machines (VMs) like VMs in Data Centers and are hosted in the cloud which does not have mature security, or any

governance practices like open to Internet without firewall or DDoS (Distributed Denial of Service) mitigation capabilities implemented. Along, with these applications there are other applications supporting a variety of business functions including product security and automation tools development, that needs to be migrated to cloud. The program consists of two sets of applications 1) Applications in on-premises that needs to be migrated to cloud and 2) Applications that are previously developed/migrated to cloud and falling in the brownfield category.

The project/program has been started recently and more details on the list of applications are yet to be finalized.

The target was to support all the migrating applications to cloud with analysis of cloud capabilities, needed infrastructure for supporting the applications, ensuring right security policies implemented, cost, and other governance practices. The challenges faced by the project/program are (1) The readiness from the application team for migration, (2) Resources from the platform team supporting the migration of multiple applications within the deadline (3) To minimize the downtime for the application/tools as these are being used by several internal teams to support their businesses (4) The Major Challenge was the level of customization on the platform security policies, role-based access control, and other governance policies needed by multiple different applications in the same cloud platform.

Centralized platform team for multiple clouds was setup to ease up the migration of applications to cloud. While the platform team is responsible for setting up the infrastructure or platform as a service component, configuration of security policies, governance practices, automation of security and threat management, and cost optimization initiatives, the application team can concentrate only on the application development, modernization, and support.

The Project Stakeholders:

Multiple business units who were owning the solutions that supported organization’s overall business needs that includes users of the applications in the Finance, Technology division, Network and Sales departments among others.

Table 6. Project C´s stakeholders.

Who	*Role with respect to the project*
Business Users (Key Business and Sales people, Business Controllers in multiple departments)	Business people with in-charge of funding the development, maintenance and sales of the application/tools
Application End users	End Users of the applications/tools
Application Development Team	Developers of the applications/tools
Application Support Team	Operations/Support Team of the Application
Platform Team	Cloud Platform/Infrastructure Team – responsible for setting up cloud landing zone for all the migrating applications and monitor overall cloud governance

Stages in the Project:

In Project C, there are two competing approaches for the application migration depending on the goal of the migration. 1) Migrate the application from on-premises to cloud and 2) Migration and modernization. While both the approaches will migrate the application to cloud (and applications that are in brownfield category will be migrated to greenfield category), the difference is the first approach will be concentrating only on the as-is migration i.e., the application will be migrated in the as-is state to the cloud whereas the second approach will also consider & implement application modernization (redesign the application).

Approach I, Migrate the application from on-premises to cloud

Migration Planning:

Steps 1 & 2. Planning and Discovery – Planning phase involves the readiness of the platform team in facilitating the migration and discovering the applications that needs to be migrated. Application Owners will be contacted or informed about their application status and readiness from the application team. Information from Application Owners on

the list of applications that needs to be migrated from on-premises or from brownfield to Greenfield will be collected. Also, all the relevant documentation for the application and other artifacts will also be collected during this stage.

Step 3. Assessment and Migration Planning – The selected application for the migration will be assessed and a report on the assessment will be delivered. This includes the infrastructure requirements like connectivity towards on-premises, end-user connectivity, cross-regional connectivity, and other required resources for the application to run seamlessly after the migration. Based on the assessment report the migration activity and exact dates for the migration, downtime information etc. will be planned.

Step 4. Security Approvals – This stage ensures all the necessary security approvals for the migration are in place before proceeding with the actual migration. This involves approvals on the data that is exposed by the application, how it is exposed, who are the end users of the application, is this an internal facing application or internet facing, does the application has all the necessary security features implemented including encryption, DDOS mitigation capabilities, vulnerabilities removal etc. This stage will involve getting approval from the Organization's central security team.

Steps 5 & 6. Iterative Migration – Once the security approvals are received and the downtime, method of migration (Rehost, Replatform, Refactor etc.,) is finalized (in Brownfield to Greenfield migration this will be mostly Rehost), the actual migration of one application will happen.

Steps 6 & 7. Once the cutover is approved and based on the feedback collected other applications will be migrated. Application team will verify the connectivity and other actions on the application availability and functioning. Platform team will coordinate with the Application Team in ensuring any actions that needs to be taken on the platform for the application to work as expected.

Figure 5 below summarizes the first approach exercised in Project C, via Migration Planning.

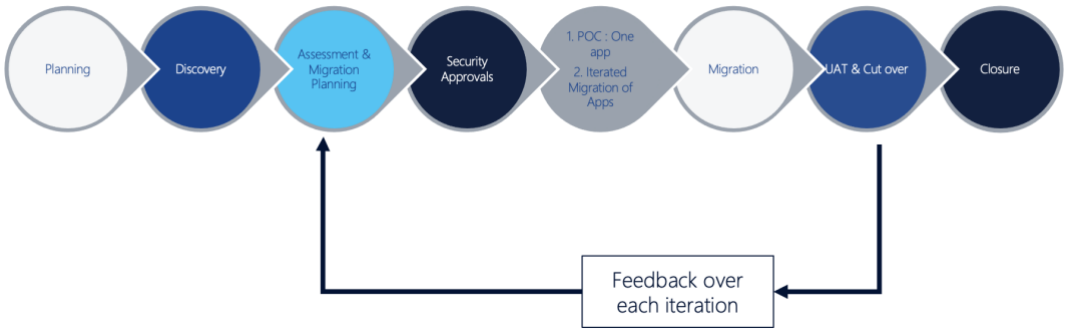


Figure 5. Project C, approach I.

Approach II, Migration and modernization

In the second approach, the application will also undergo modernization in addition to migration to the cloud, leveraging the maximum potential of cloud.

Steps 1 & 2 – Initiate, Assess & Plan – this will be same as the Steps 1-4 in the Approach I, expect the migration plan which in Approach I will be mostly Rehost, whereas here it may differ according to the application team inputs and readiness for the modernization. This will be completely owned by the Platform team.

Step 3 – Migrate – Actual Application modernization will take place in this stage and it involves complete code and configuration changes in the application. Platform team will coordinate with the application team in setting up the necessary infrastructure, resources and other components needed by the application. Once the migration and modernization is completed the application team will perform the functional testing, verify application performance and other functionalities.

Step 4 – Cutover – After successful testing and completion of stage 3, the application can be moved to the production environment in cloud. Platform Team will be responsible for the infrastructure and other governance practices. Application Team will be owning these stages and coordinate with the application end users and the platform team.

Figure 6 below summarizes the first approach exercised in Project C, via Migration and Modernization.

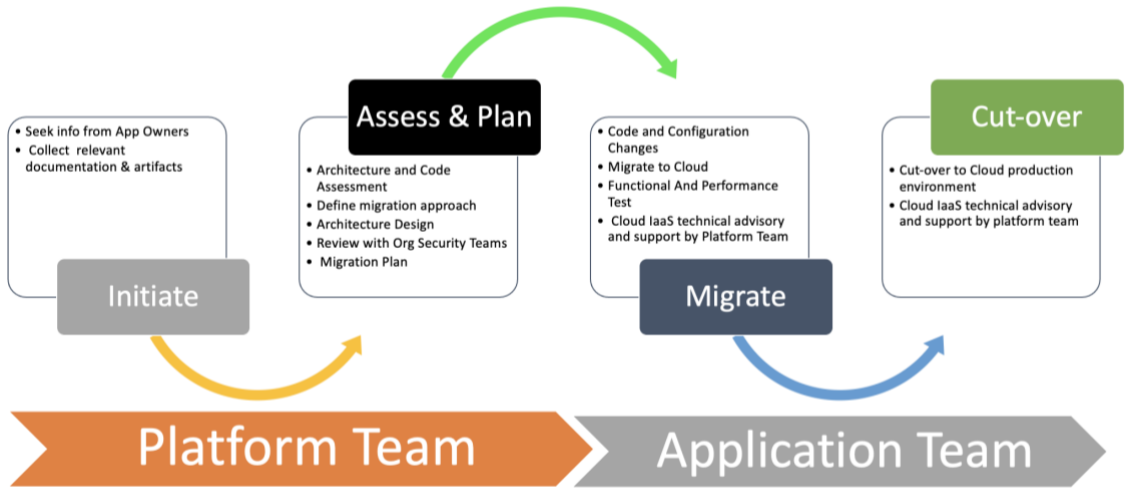


Figure 6. Project C, Approach II.

Problems:

The cost incurred by retaining the application in on-premise environment and the age of the application itself i.e., lack of enough knowledge in migrating the application without the fear of breaking it during migration and fixing would be complex. This also reflected in the application modernization as this would again mean a whole new project which will incur additional cost and maintenance/support for the existing application. The communication gaps that can exist between platform, security and the application teams that can include confusions in owning or overdoing roles and responsibilities of the teams itself unless documented.

The Project Strength & Weakness in terms of Cloud Optimization process:

The main driver of the project/program was the cost incurred by the applications and the on-premises data center rampdown. The objective was to migrate the applications which required high maintenance and support costs. The project/program emphasize on the usage of Platform as a Service (PaaS) services and Infra as a Service was used only when necessary. Optimizing cloud platform scaling based on usage and cost statistics will be part of the activity at least partially.

Table 7. Project C, strengths and weaknesses in terms of cloud optimization.

Positive	**Negative**
Migration to the cloud with optional application modernization	Might delay the overall timeline for the application go-live
Central Platform Team setting up the infra, security and other governance practices. Application Team can concentrate only on the application development	Multiple teams are involved which can cause delays but should be mitigated by proper planning, coordination and communication
Cost Optimization initiatives– this was part of the central platform team as part of regular standard and the application team wouldn't need to spend additional efforts in establishing these, except for the application itself	Focus on the Cost Optimization Initiatives – Although it is advised to do the application modernization and ramp up the application monitoring, not all the applications might opt-in for the modernization but only migration
Ramping down of legacy systems, on time migration of all the solutions to the cloud	Centralized Team exists but has minimal experience of documented best practices and guidance for the application migration.

The main challenge is based on the different application functionalities and the different migration approach that needs to be taken for every application. While some of the application may be utilizing the Rehost approach, applications that opt for modernization will need to consider the best possible approach. Both the application and the platform teams might require additional support from the cloud experts in the relevant cloud service provider for finalizing the approach taken for the migration depending on the application nature and functionality. One of the Stakeholders stated that:

> "*The Platform team ensures all the necessary infrastructure and connectivity in place and the next step is to start offering security hardened templates for actual deployment of resources. This can ease up the efforts needed by the Application Team, who can purely concentrate only on the application development then". (Respondent 3)*

The Project Current Status (as of now):

The current situation is that the platform team has developed multiple automations to get the necessary infrastructure, connectivity supporting multiple scenarios, implementing security policies, governance practices and other cost optimization initiatives. This has been tested and working for the applications that are currently present in the Greenfield cloud. The business and application teams are currently performing this as part of their roadmap plans and currently only a very few applications are being shortlisted/marked for migrations.

3.3 Key Findings from the Current State Analysis of Three Cloud Migration Projects

As seen from the analysis above, Projects A and B demonstrate a lot of similarities in the approach taken, development and the operational handover stages.

With respect to the *Assessment* phase, which is the **Step I** in Project A, all the applications were analyzed and categorized as to be migrated or developed in cloud or marked for ramp down and then the approach of migration was decided. In Project B, it was already decided to be developed in cloud and hence the *Assessment* phase was missing; instead it included the Request for Proposal (RFP) from multiple cloud providers and **Step II** included a Proof-of-Concept (PoC) or demo of the capabilities with respect to the project.

Apart from these steps, other steps included the *Design and Development* of the capability in cloud, hiring third party developers because of the lack of in-house development capabilities, *Testing, Additional developments* and *Enhancements*. Only after the operational handover was completed, automation and optimization techniques were considered and started to be developed.

Also, as these projects were mainly the initial projects to be developed or migrated to cloud, there was lack of proper knowledge, training and the team was less aware of the automation and other optimization techniques. Case Projects A and C both had the *Discovery and Assessment* of the applications stage wherein the applications are analyzed before being categorized for migration and decide how the application will be migrated (refactor, rehost, rebuild, repurchase and replatform).

Case Project C is quite different from the other two projects A and B, as it was already in Cloud and the cloud platform/infrastructure was developed and managed by the

centralized platform team. Project C also had a clear distinction between the roles and responsibilities of the Platform Team and the Application Team. Another notable difference between Projects C vs. A and B, is the security review that happens in the design stage itself which addresses any compliance related issues and addresses cost of redevelopment or separate development efforts too.

If summarized, the lessons learnt from these three recent could migration projects may look as follows (see Figure 7 for the illustrations of lessons leant).

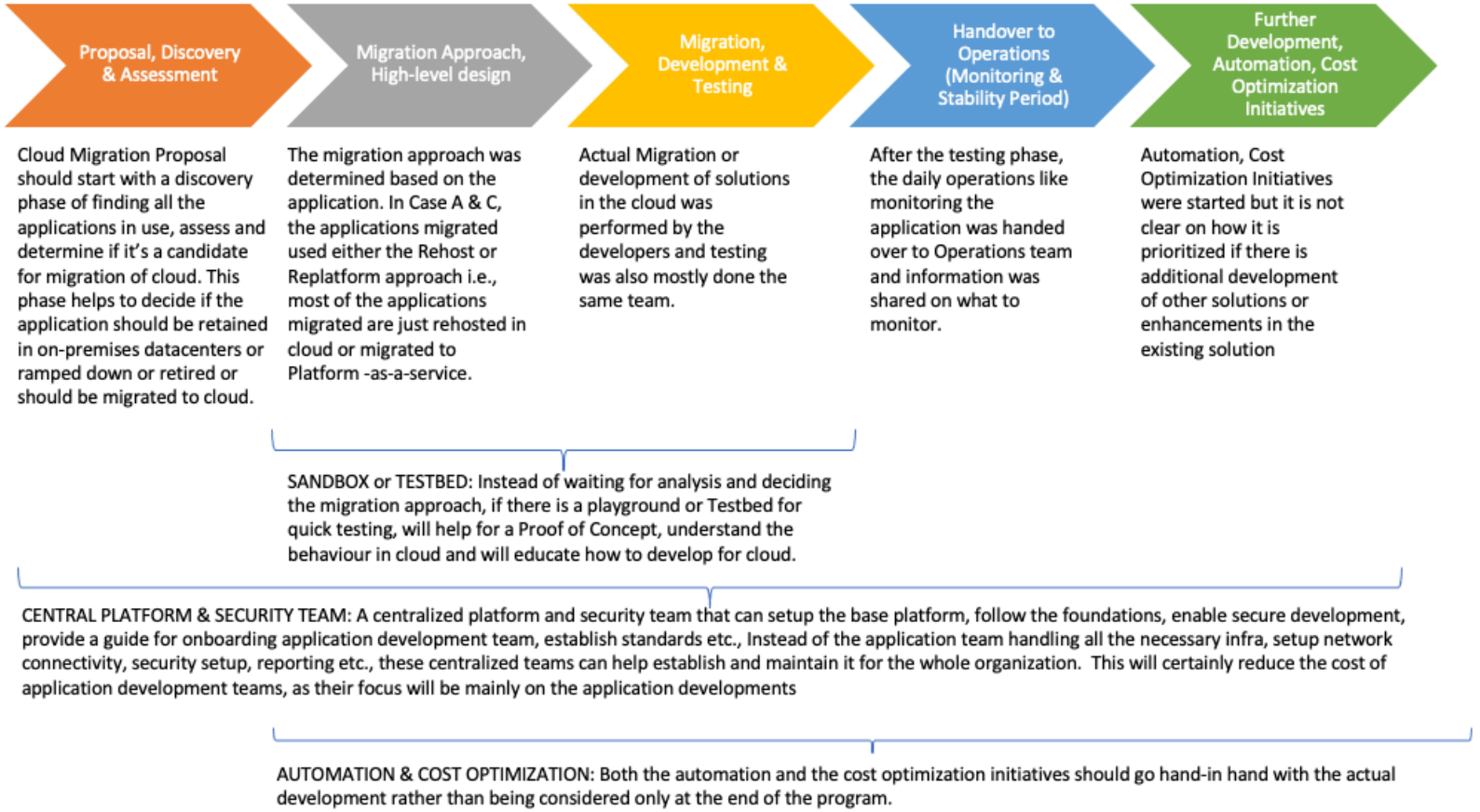


Figure 7. Main steps in the cloud migration/development (generalized from three case projects).

3.3.1 Lessons learnt

The main steps that were followed in all the case projects A, B and C (except for the Cost optimization initiatives which was considered early in Project C as this was also partly handled by the Platform Team) can be summarized with the picture in Figure 7 below.

1. *Proposal, Discovery & Assessment* – Discover the applications that needs to be migrated and decide if this application needs to be migrated to cloud or ramp-down or continue in the on-premises itself. This will later save a lot of efforts and cost if it's decided not to be migrated. This phase needs more time for the analysis and properly analyzed. An incorrect analysis would result in lot of efforts spent in migration only to find that it should've been retired or ramped down instead. The phase doesn't include any steps to define the optimization objective or even considering the cost impact was known to be made in this phase.

2. *Migration Approach, High Level design* – This phase determines the path of the actual migration of the application or modernization of the application if its already in cloud. Most of the applications migrated in case A and C are taking the approach of rehosting the application in Infra-as-a-Service in cloud or replatform the application (change the underlying platform to cloud provider for managing). No efforts or steps taken to rearchitecture the application to use the cloud native resources for more effectiveness and reduced cost.

3. *Migration, Development & Testing* – In this phase, the actual work of migrating the applications or developing the application in cloud was done by the developers. Testing of the applications for the expected behavior was mostly done by the same team that developed the applications. This is the phase where the actual *Proof-of-Concept, Demo or Pilot Test* was done (except in Case B as this case was developing a solution directly in the cloud). Ideally this could have been done well before this stage itself. Consider doing a Proof-of-Concept (PoC) and a demo of multiple cloud providers, to analyze their capabilities and to assess which will best suit the needs of the application to be migrated. Pilot test the application by building application with few capabilities for testing purposes. Ensure the team doing the pilot test has the cloud competency in addition to the application knowledge. In this phase too, most of the developments were done

manually via clicking the resources in a Graphical User Interface (GUI). No steps taken to automate the code or Infrastructure-as-a-code options weren't explored.

4. *Handover to Operations* – Only in this phase the Operations team was introduced to the cloud & information on what needs to be monitored was shared with the Team. It is a good practice to have a stability period and the development was responsible for fixing issues during this time while the operations team is still learning. However, the responsibilities of the operations team need to be clearly documented and the team needs to trained to handle all the activities expected out of it including monitoring the application, platform or infrastructure, handling other operational activities including service management activities. This phase again followed the traditional approach of manually monitoring the services using the GUI, without any automatic reports of the resource health or issues with the application.

5. *Further Development, Automation & Cost Optimization Initiatives* – Automation and actual Cost Optimization Initiatives was even considered only in this phase; however, the priority of these initiatives was reduced whenever there is a new development or enhancement requests.

In addition to the above, the lessons learnt from Case A and B (except in case of Case C) include:

6. *Centralized Team* – It can be seen where the centralized team doesn't exist or is considered weak, there is less or no documented best practices and guidance. Also, this leads to the development team developing the platform and necessary infrastructure for the application. This delays the overall timeline of the projects and demands additional learning for the developers who might have only application knowledge. Publish the documented best practices and guidance from the centralized team on the roles and responsibilities, things to do in cloud, how-to guides etc., in a sharepoint or a common location that can be accessed by multiple teams.

7. *Security Team* – Security in cloud is again a vast area which when not configured properly can provide way for insecure settings/configuration that would result in hacking or stealing of the organization data, resulting in losses and reputation beyond fixing. Security needs to go hand-in-hand with the actual development

and monitoring. Like a centralized team of handling the platform or infrastructure, a centralized security team is also deemed necessary.

8. *Learning Curve, Continuous learning* – The application team might have complete understanding and knowledge of the application itself, but cloud is a new and vast area with new features releasing every week if not days. This means the application team and others working with Cloud based applications needs to improve their competency with respect to cloud. This needs to be continued on a regular basis, so as to develop, test and continuously improve the solutions that were previously developed.

9. *Foundations for Cloud* – Design the cloud foundations that can scale well, secure and compliant. Consider the resources for the cloud foundation like Identity and Access Management, Connectivity from on-premises data centers, office locations, network connectivity, security policies, level of control by multiple teams, billing, infrastructure etc.

The current state analysis of these case projects identified the lessons learnt from the current processes, related to cloud migration and continuous optimization of cloud resources, based on the three project cases. It considered the Cloud migration stages of the three case projects and the stage where the application is already in Cloud. The stages of the current cloud optimization process in each case project and, based on the above, generalized the overall map for such a project based on the lessons learnt.

In both Case A and B, the *Optimization* was considered as a phase in the project rather than being involved as an activity in all the phases. In Project case A, it was evident that even today there has been a lack of adopting DevOps culture and other automation activities. It also reflected the priorities of the management in allocating tasks. The situation has been improving but it wasn't in a good state or, at least, there is more focus needed on automation and the cost optimization initiatives. In Project case B, more focus on the automation and cost optimization initiatives/process has been done since the go-live. The initiatives have resulted even in changing vastly the tools and the architecture put-up in place during the initial stages – with several solutions that was initially put-up being replaced by more cloud native or PaaS solutions. Automated monitoring of resources, application KPIs were created that resulted in Operations team actively contributing in the DevOps process.

With the advent of Centralized Platform Team and the security teams, more focus is put on the standards, automated services, security configurations and monitoring activities which are prioritized rather than just focusing only on the new developments. Unlike in Cases A & B, for Project case C, the centralized platform and security teams exists providing documented guidelines for security vulnerabilities remediation in cloud, on-boarding assistance, establishing network connectivity and to facilitate all necessary infrastructure for the application to work. However, the challenge here may be attributed to the fact that lack of in-depth application knowledge may force the application development teams to go with approach – I i.e., Migrate the application as-is to the cloud (or from brownfield to greenfield setup). Also, the optimization process will be needed to be applied on the application level – for example, an application can run on an over-scaled Virtual Machine which is underutilized.

The current state of continuous optimization of cloud resources includes the platform team automating the process of identifying the underutilized resources, redundant resources, idle resources, suggesting alternate approaches in the solution architecture - making use of shared resources etc., and updates reports about security vulnerabilities, hardening of security configurations for the resources by establishing centralized control and monitoring of critical components.

The current state analysis revealed the fact that in both projects A & B, cost optimization initiatives weren't part of the Cloud Migration and was considered only after the application is already migrated to cloud. No steps were taken either to use the infrastructure-as-a-code and build the CI/CD pipelines while doing the migration or describing the goals for cloud cost optimization. This was realized only after the go-live happened and the application is considered running stable in the Cloud. Even after this stage and in the current state, the cost optimization initiatives that were considered didn't follow a structured process and was considered just as an improvement factor rather than a sustained optimization process. This was evident from the fact that, these programs or initiatives were given less importance when compared to the actual application updates/changes. Also, the roles and responsibilities were not clearly defined or unknown for the developers involved in building/migrating the application i.e., who will build the platform for migration, who will be responsible for the platform security, patching the infrastructure etc.,

While in the case Project C, the infrastructure-as-a-code and the CI/CD solutions that were built for enabling the platform in cloud, for smooth migration of application to cloud

were as a result of the larger Cost Optimization processes that was initiated during the early stages itself. Manual configuration was considered only as a last resort, when the automation wasn't possible. This enabled atleast two options for migration to the cloud. The onboarding time for the migration is vastly reduced because of the automation that was developed. Moreover, there was no confusion in the roles and responsibilities as the application and platform was considered as separate entities and multiple teams controlling them. Platform or the centralized team would control all aspects of the platform including improvements to the automated CI/CD pipelines that was developed, security configuration, connectivity etc., while the application team's responsibility is to manage the application.

3.3.2 Selected Focus Areas

Case Project C introduced most of the options that was missing in the Case Project A and B like the centralized team, automation which is considered as a major step in the cost optimization process. Another difference in the case projects is the responsibility of Governance – in case project C the centralized team or the platform team had a clear role or was responsible for the Cloud Governance.

As seen from the analysis above, the following two areas made the most challenging or the missing parts between the Case Projects A, B & C:

First, *Automation & Centralized team is missing or not utilized effectively* – this team should be concerned with developing automation techniques such as creating a landing zone, blueprint for the platform, utilizing the infrastructure-as-a-code (IaC) templates for building infrastructure which helps to easily deploy the needed infra for multiple teams, embed security into the design, version control and be reused. Also, having a centralized team who can take care of platform/infrastructure and security can reduce the efforts of Application team in developing their knowledge on these parts and can still focus on the application needs rather than spending time in learning, experimenting and building the infrastructure.

Second, *Cost Optimization & Governance – Cost optimization* is an ongoing and an iterative process that includes cloud strategy, design, planning and operations. *Cloud governance* is an important component of the Optimization that can affect the outcomes

– creating policies and ensuring the right process exists, followed and enhanced continuously for cost improvements in cloud.

The findings from the case project C already asserted the needs for automation and the impact of governance – providing clear visibility of the roles, responsibilities. Thus, the focus areas if developed further in the future would result in not only realizing the benefits but also provide a long-term optimization process for the case company. For this end, it should be important to explore the existing knowledge and available best practice how similar challenges are approached by other companies, in other projects. For this end, these two topics will be further discussed in Section 4 wherein it can be seen how these practices can address a wide range of cost and other challenges.

4 Existing Knowledge and Best Practice of Cloud Optimization and Governance

This section discusses the available literature, studies, best practice, and white papers. Previous Section 3 focused on the current state analysis of the project cases in cloud migration. This Section 4 seeks for insights from literature on optimizing automation and centralized team, and cloud governance, and thus influence the cost optimization, based on best practices in cloud.

While there are multiple tools suggested in the literature for the purpose of Automation, Continuous Deployment, Continuous Integration, Governance and cloud providers themselves on the reservation purchases, the below section will discuss the topics of Cloud Automation, Cloud Governance, Centralized Team (Cloud Center of Excellence and FinOps) in the context of Cloud Optimization. It is done with the purpose to improve the case companies could projects based on this available knowledge (in Section 5).

4.1 Challenges of Cloud: Overview

Cloud Computing (often referred as Public Clouds or simply Cloud) is the delivery of computing services through Internet, on-demand. The services include servers, storage, database, network, software, analytics and intelligence. Wikipedia (2018) defines Cloud Computing as, "*Cloud computing is the on-demand availability of computer system resources, especially data storage (cloud storage) and computing power, without direct active management by the user*."

There are three cloud computing deployment models – Public, Private and Hybrid.

Public Cloud Model is the most popular cloud deployment model. In the public cloud model, a third-party cloud service provider (CSP) delivers the cloud services over the internet. These services are sold on demand and are charged based on the usage of the actual services or resources. They are billed according to the usage per-second, per-minute or per-hour usually or through long-term commitments. Customers only pay for what they use. Leading public CSPs include AWS, Microsoft Azure, IBM and Google Cloud Platform (GCP), as well as IBM, Oracle and Tencent.

Hybrid cloud is a combination of public cloud services and an on-premises private cloud, with orchestration and automation between the two. Companies can run mission-critical

workloads or sensitive applications on the private cloud and use the public cloud to handle workload bursts or spikes in demand. The goal of a hybrid cloud is to create a unified, automated, scalable environment that takes advantage of all that a public cloud infrastructure can provide, while still maintaining control over mission-critical data.

Private cloud services are delivered from a business's data center to internal users. With a private cloud, an organization builds and maintains its own underlying cloud infrastructure. This model offers the versatility and convenience of the cloud, while preserving the management, control and security common to local data centers. Internal users might or might not be billed for services through IT chargeback. Common private cloud technologies and vendors include VMware and OpenStack (As summarized from, Chai & Bigelow, 2017)

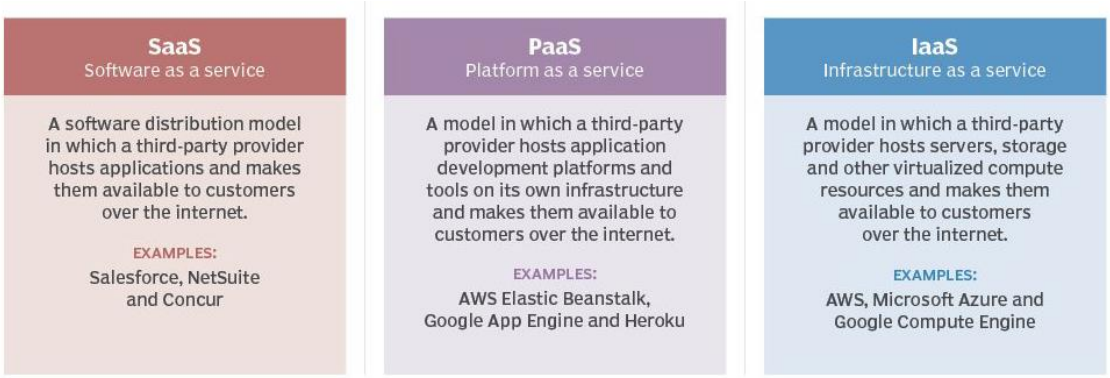


Figure 8. Cloud Computing Deployment Models (TechTarget 2017).

Business practice shows that when companies think of cost optimization in cloud projects, they first start looking at the Public Cloud. Public Cloud is a powerful technology, but it has many hidden challenges.

One for the main (if not the most) important reason for most companies to migrate its applications and servers to public cloud is to reduce the expenditure of the infrastructure costs. Adding to the maintenance, the existing infrastructure will phase-out in few years forcing changing the entire stack of servers. These costs can be reduced with almost zero capital expense when migrating to cloud. However, Cloud Cost (operational) continues to raise and wasted spend along with other factors becomes more critical challenge to the companies that have migrated their solutions to cloud.

Flexera (2022) published a report, known as ”2022 State of the Cloud Report”, which discusses in detail about the wasted spend, challenges faced by companies in controlling cloud spend, and the issues of cloud optimization at various depth. The report illustrates the extent of wasted spend in cloud migration projects (based on the responses of 753 respondents from a survey conducted in late 2021, and the respondents are mainly cloud decision-makers and users in their respective companies). Figure 8 shows the amount of wasted cloud spent based on Flexera´s estimations.

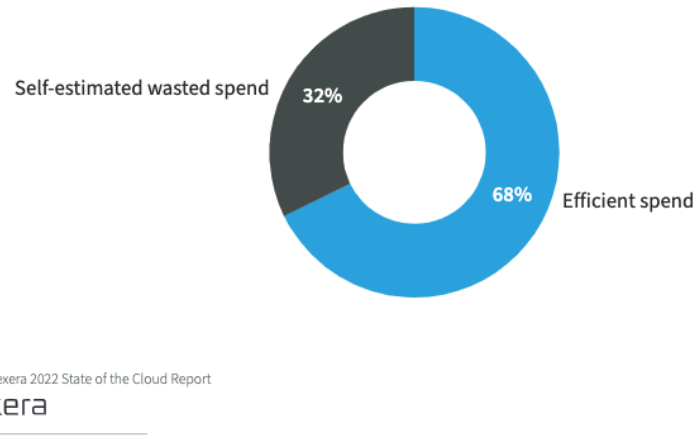


Figure 9. Self-estimates of wasted cloud spend in all organizations (Flexera 2022).

As seen from Figure 8, the wasted spend reaches a considerable 1/3 of the expenses, which makes a significant loss for companies. The report also highlights year-over-year (YoY) changes on the top industry challenges faced by businesses in managing cloud and controlling costs related to cloud. Based on the report, today's top challenges for organizations of all sizes are *Security*, *Managing cloud spend,* and *Lack of resources or expertise*, and *Governanc*e, followed by other challenges such as Managing software licenses, Compliance, Cloud migration, Managing multi-cloud. These challenges are shown in Figure 9 below, with the top four challenges highlighted.

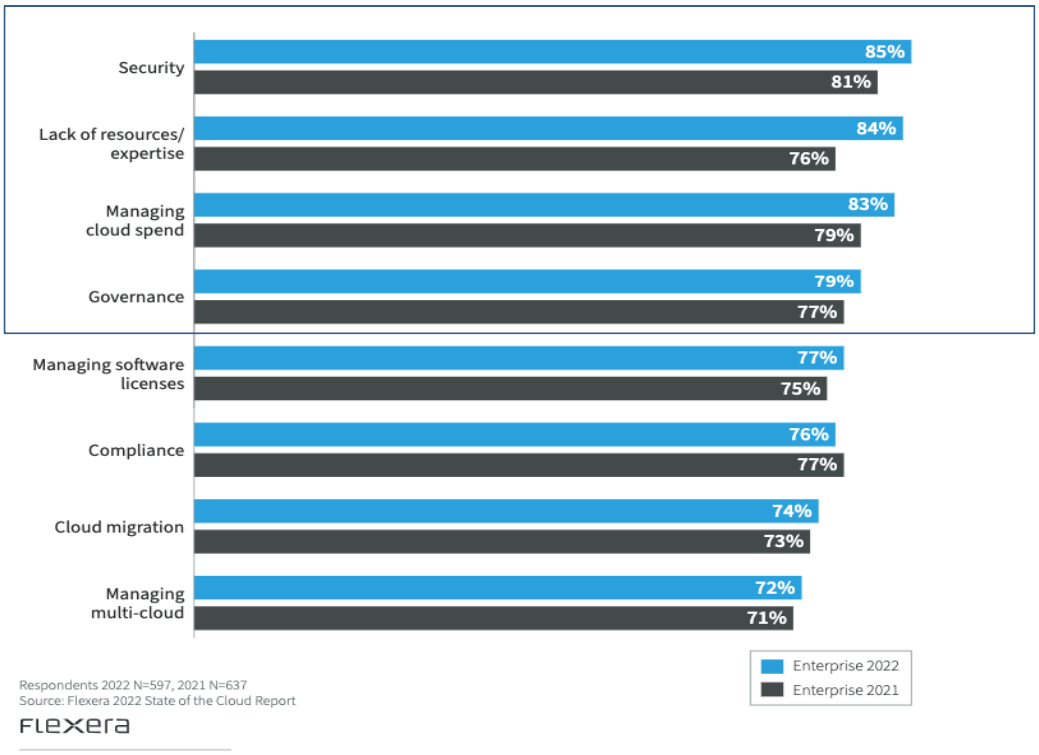


Figure 10. Self-estimates of wasted cloud spend in all organizations (Flexera 2022).

As shown in Figure 9, the following challenges are associated with the cloud (Flexera 2022).

First, *Security:* Application and Data Security is one of the significant challenge being faced by companies. If not dealt carefully, data breaches can cost a company severe damages to the cost and reputation. As threats have evolved and sophisticated new attacks emerge, it became more important than ever for businesses to embrace security-first mentalities.

Second, *Lack of resources/expertise:* Cloud is developing fast, and to keep pace with the technology is challenging. Companies that are using cloud technologies needs to invest in their internal or hired resources to make sure that they stay on top of the knowledge base and required skill set for smooth development and operations.

Third, *Managing cloud spend:* Multiple services within the cloud needs to be enabled and utilized when developing or running applications and these actions incurs charges. The costs charged by the cloud service provider is not straight forward to understand in most cases.

Fourth, *Governance:* Poor governance makes it difficult to trace the costs, issues, and especially human resources that might not be needed anymore and thus add to additional costs. As one popular example of a governance chapping, without proper tagging or identification it is hard to find if more (or less) specific resources are needed, or even who is actively using some human resource now, and for which goal. (As summarized from: Flexera 2022 & Disha Babla, 2019)

This example of most typical challenges of cloud projects confirms the conclusions from the current state analyses done earlier in Section 3, which found that the case company of this thesis is also confronted with the same problems. Other challenges that business typically face (but either already overcome or not faced that significantly by the case company of thesis thesis) include:

Fifth, Managing SW licenses: Migrating to the cloud does benefit most Enterprises however the management of licensing does not become less difficult. This involves knowing the agreement that an organization has, license model and the effect of rights of using the licenses. Also, monitoring the usage of the licenses becomes more and more complex. While the cloud providers support 'Bring Your Own License' (BYOL) models, licensing in cloud is quite challenging for any enterprise.

Sixth, *Compliance:* Organizations need to wary of the compliance standards they need to fulfill on migrating to public cloud and while developing in cloud. Most applications rely on data from end users and depending upon the nature of data, there are multiple compliance policies and regulations that needs to be applied.

Seventh, *Cloud Migration:* As the cloud adoption is growing rapidly, companies that want to migrate to cloud is missing the proper cloud migration framework that can help to draft a robust plan for the migration.

Eighth, *Managing Multi-Cloud*: Although this is most applicable for the enterprises, at present all the companies including SMB are looking for multi-cloud options, to avoid vendor lock-in. The challenges associated with this are managing the technical knowledge for the teams involved, developing solutions & standards, monitoring & maintenance, choosing the right cloud for the intended service or application development. (Flexera 2022.)

Apart from the challenges mentioned above, the other challenges include

- *No visibility* to executive teams *over increasing cloud costs.*
- *No consolidated view about cloud costs* distribution based on application data, infrastructure usage patterns and IT budget planning.
- *No organized, orchestrated efforts toward reducing cloud costs.* Reducing cloud costs is majorly a function of a few engineers (majorly DevOps).
- *No actionable control of executive & finance teams over cloud costs*. (summarized from: Disha Babla, 2019)

These challenges (all of them or some of them more prominently than others) are faced by businesses when dealing with the cloud. Some companies, especially those with access to available resources and necessary expertise, are able to get control of their cloud more successfully than others. One of such examples is Airbnb, and this example is described below to give a clue how the cloud challenges can be overcome.

Case of Airbnb in controlling Cloud costs

Airbnb a popular travel accommodation booking website Airbnb realized it had a big problem: Its monthly Amazon Web Services (AWS) cloud bills were growing faster than the company revenue.

> "*We had a problem, but we lacked an in-depth understanding of how teams use AWS resources, and how planned architectural and infrastructure changes would impact our future AWS costs*". (Rice & Matlin 2021)

When this was realized, the technology teams aligned and worked on the below areas:

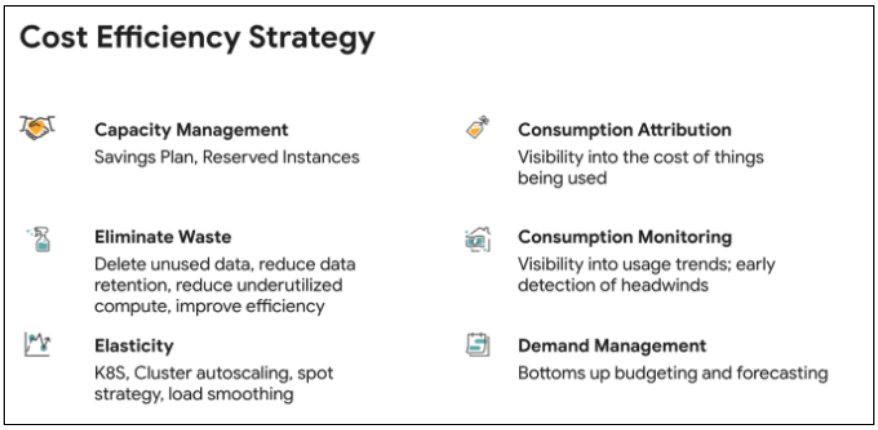
1. **Measurement & Accountability**: creating a clear accounting structure for all AWS usage aimed largely at understanding holistically how we consume and utilize AWS services.

2. **Cost Efficiency**: identifying and eliminating waste

3. **Process & Governance**: defining operational process and guardrails to inform decisions, and improve our ability to forecast future demand.

The Airbnb engineers set out to build up the cost-attribution data required to start to show its data-driven developer community just how big a problem they were facing to gain some buy-in to FinOps. The technology teams were provided with necessary information to make tradeoffs between cost and other business drivers. The visibility to cost drivers helped engineers to identify the architectural design changes to reduce costs and identify potential cost headwinds. Their receipt for success includes:

"A centralized cost efficiency team with a birds-eye view of the entire Airbnb ecosystem can observe changes and make centralized purchasing decisions accordingly." (Rice & Matlin, 2021)



The report concludes with the information that due to the efforts taken by the developers, *the Central core team,* and due to the measures taken in the cost-efficient strategy, Airbnb saw a $63.5 million year-over-year decrease in hosting costs, which contributed to a 26% decline in Airbnb's cost of revenue in the nine months that ended in September 2020.

Source: Rice, J. and Matlin, A. (2021). "Our Journey towards cloud efficiency" published by Airbnb engineers on Apr 6, 2021.

Thus, taking the optimization initiatives into the focus of this section, the most important topics that will be covered in detail in this section are:

1. *Automation (DevOps)* – Cloud automation defines the deployment and management of tasks to be automated, and cloud orchestration arranges and coordinates those defined tasks into a unified approach to accomplish intended goals.

2. *Governance in Cloud* – Every organization wants to keep entry of every resource in the organization, but also the security policies and other practices that is followed in the organization. Cloud governance provides the set of principles to the management for the effective and efficient functioning of the system. It enables the achievement of the objectives of the organization. The efficient utilization of resources helps in the reduction of the cost.

3. *Centralized Team* (Cloud Center of Excellence & FinOps) - CCoEs are used to bring together a diverse, knowledgeable group of experts from across the organization to develop best practices for the rest of the organization to follow.

These topics are discussed in more detail below.

4.2 Cloud Automation

When talking about Cloud, Cloud Costs Optimization, Cloud Governance the most important buzzword among developers is DevOps. According to Hall (2022):

> *"DevOps best practices include agile project management, shifting left with CI/CD, automation, monitoring, observability, and continuous feedback*."

Adopting DevOps requires a business transformation of structures and processes, therefore, it is important to discuss in more detail about the automation principles of DevOps. (Hall 2022.) The DevOps principles include:

First, '*Automate Everything'* is the key principle of DevOps. Automation starts when the developer pushes the code to the source repository, continues to the deployment of the code and even to monitor the application and system in production. Automation takes a central stage when talking about Cloud Cost Optimization. (Hall 2022.)

Next, in an article published by DevOps.com (2 August 2017), "All Day DevOps: Modern Infrastructure Automation", Derek E. Weeks explains the role of automation in the modern infrastructure wherein he defines automation into three broad categories such as:

1. Infrastructure Automation
2. Application Automation
3. Compliance Automation. (Weeks 2017.)

The article also reports about the '2016 All Day DevOps Conference' wherein, "*Several speakers of All Day DevOps talked about automation, and all of them said a critical step is to treat infrastructure as code*". This "*Infrastructure as a Code"* approach seems to have been gaining ground since that time. Experts working in this area come to conclusions that, in order to implement automation at scale, companies need to start with a dynamic infrastructure by:

1. Provisioning and setting up environments

2. Implementing dynamic scaling of compute resources

3. Migrating legacy workloads to the cloud

4. Deploy in multi-cloud and hybrid-cloud environments

5. Support heterogeneous environments. (Infrastructure Automation, Nathen 2016.)

First, in terms of *Infrastructure automation,* Infrastructure *as a Code (IaC)* is a form of configuration management that represent an entire organization/platform or application's underlying infrastructure in a code (text) format. Treating every infrastructure as a code allows reuse, automate, programmatically provision the infrastructure components such as servers, databases, network configurations, tools, firewalls etc. This also includes version control and testing embedded into the code or the pipeline for configuring the infrastructure. Imagine a case, where a development team needs to configure the platform required for running their application. Infrastructure is treated the same way an application is treated in an environment; it shares same pipelines; it is version controlled; it is reusable as current configuration changes are considered while catering for any new request for new infrastructure. Goal: consistency of the build. (Sabharwal et al. 2021.)

According to Weeks (2017), with "Infrastructure as a Code", the same code can be used to scale elegantly from one to tens of thousands of managed components across multiple complex environments.

Second, in terms of *Application Automation*, according to Harvey (2016), modern applications also look like Infrastructure as code.

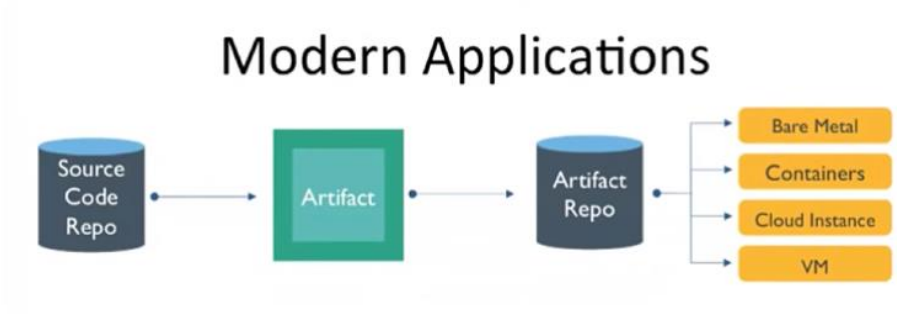


Figure 11. Modern applications approached as "Infrastructure as a code" (Harvey 2016).

As shown in Figure 10, Modern Applications also look like Infrastructure as Code. Developers can make applications that Operations can deliver and run in the production. This makes it easier to consume, run, and keep applications healthy. (Harvey, 2016) Many new applications are being created and developed to run in cloud-native environments. Some common elements across multiple systems that help developers and deployment teams automate their continuous deployment releases are: Support for Simplification of Deployments – Docker, Jenkins, Tekton etc., allow developers to simplify deployment of application in the cloud environments. Some of the tool's support YAML format and Python templates.

The speakers at the *'2016 All Day DevOps Conference'* conference (Weeks, 2017) also stressed the need for *the application automation*. Developers can make applications that operations can deliver and run in production. This makes it easier to consume, run, and keep applications healthy. Operable applications need to be:

1. Isolated
2. Immutable
3. Configurable
4. Built on a common interface for monitoring health
5. Rebuildable from sources
6. Reside in common packaging
7. Maintain runtime independence. (Weeks 2017.)

As enterprises implement infrastructure, application, and compliance automation, it creates a freedom to focus on the people (i.e. managing and developing employees), and people are the key (Weeks, 2017). Rather than focusing on the deployment of the platform and the associated infrastructure elements and then redefining deployment strategies, the continuous deployment tools help the teams focus on the application, select the appropriate deployment strategy, and reuse the templates for future modifications (Harvey 2016), thus sparing resources to focus on the core business issues rather than technicalities.

Third, in terms of *Compliance Automation,* i.e. considering security compliance as a code (it means, applying a similar approach to other elements of Infrastructure as a code), can be part of the DevOps pipeline. For example, Nathen Harvey, VP at the Community Development of Chef, while speaking at the '2016 All Day DevOps Conference', advocates *managing compliance documents as a code*, too. By translating the

compliance into a code, it can be executed as part of the pipeline and can be tested for compliance throughout the entire life cycle. (Weeks, 2017.) Furthermore, Bird (2016) in his famous book 'DevOpsSec' argues for the same approach and suggests incorporating security and compliance into the code. "*Security as Code uses Continuous Delivery as the control backbone and the automation engine for security and compliance."* Bird (2016) gives the following details about the various steps in practicing Security and Compliance as a code:

- Doing secure design in DevOps,
- Writing secure code in the continuous delivery,
- Performing security testing, and
- Securing infrastructure (Bird, 2016.)

As with Compliance, the author details about

- Defining Policies Upfront
- Automated Gates and Checks
- Managing Changes in Continuous Delivery
- Separation of Duties in the DevOps Audit (Bird, 2016.)

By having all the security configuration as part of the infrastructure as a code, there is no separate need for manually configuring security into the components, addressing vulnerabilities will be easier as the code will be modified and can be used to deploy the changes to all the affected resources. For instance, if a company has a policy not to open ports to the public IP addresses or not to create public endpoints for a storage service, this can be embedded into the code and developers/operations personnel when using the code to create the storage resource or a particular service will be automatically adhering to the standards set by the company. A policy to not allow creation of public IP addresses can be applied on a specific project or across the entire cloud for an organization can block even accidental creation of the resource. (Bird, 2016.)

Bird (2016) also describes a model for adding security checks in the continuous delivery workflow that is shown in Figure 11.

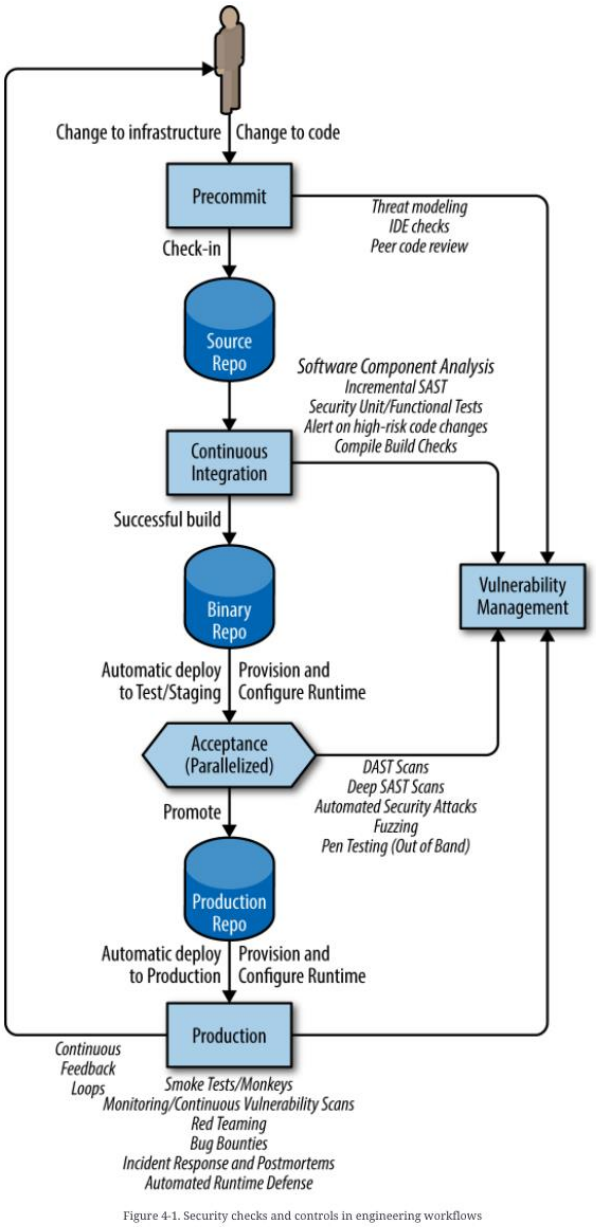


Figure 4-1. Security checks and controls in engineering workflows

Figure 12. Security checks and controls in continuous delivery workflows (Bird, 2016).

Figure 11 illustrates a model on how and where to add the security checks and controls into the continuous delivery workflow. When a change to the code is made, at the precommit stage the threat modelling, IDE checks and peer code review is done after which the code is successfully checked into the source repository. With the continuous integration configured the build is done and checked into the Binary Repo and an automated deployment to Test or staging is done, where an acceptance test is carried out using several methods including Pen Testing. Once this is done the code is then checked into the Production Repo and is automatically deployed to Production. The

Continuous feedback loop from production ensures the infrastructure/code is constantly enhanced as a result of Incidents or changes. (Bird, 2016.)

Summing up, Cloud Automation helps in removing the manual errors, increasing the number of deliveries, embed security practices into code (Infrastructure as a Code, Compliance and Security as a Code), enables speed, reliability and consistency. The continuous deployment tools based on best practices across various organizations ensure standardization of deployment processes, template reusability, deployment of immutable images, fully automated and fast application rollouts, and the capability to perform rollbacks if there are issues (as summarized from “Pro Google Cloud Automation” by Navin Sabharwal, Piyush Pandey 2021). These in turn helps to optimize the cost spent by organizations in reducing the cost of expert resources, reduces cost due to security issues and fixing those and empowers other team members to develop solutions. However, automation still needs to be couples with smart Cloud Governance, which is discussed in the next section.

4.3 Cloud Governance

Cloud Governance refers to the structures, policies, process, and systems for the direction, control and the activity monitoring of a company. The goal of cloud governance is to enhance security, data security, manage risk and ensure smooth run of the operations. (Imperva n.d.) According to Gill (2022), six governance principles for cloud-based solutions for effective governance include:

1. Financial management,
2. Cost Optimization,
3. Operational Governance,
4. Performance management,
5. Asset Management,
6. Security Management (Gill, 2022).

One of the most advantages of Cloud is the flexibility and ease of development, which makes the teams within an organization to develop the systems with a single click. However, this can cause issues such as

- Poor integration between cloud systems, even within the same organization

- Duplication of effort or data between different parts of the organization
- Lack of alignment between cloud systems and business goals
- New security issues—for example, the risk of deploying cloud systems with weak or lacking access control. (Imperva n.d.)

These issues together will add to the cost incurred in addition to the security issues. With proper Cloud Governance these issues can be addressed, so that Cloud Governance can

1. Improve Cloud Resource management – Promotes efficient spend
2. Reduce Administrative Overhead
3. Improves Cloud Security and Compliance. (Imperva n.d.)

In large enterprises and mid-scale organizations, there will be multiple business units who are responsible for developing their own solutions in cloud and managing the Cloud Resources (Servers, Databases, Storage etc.,) can be more complex. According to the Microsoft documentation on Cloud Governance, "*Cloud governance creates guardrails that keep the company on a safe path throughout the journey*". (Microsoft, 2022a.) The documentation also mentions about the five disciplines of Cloud Governance as it can be seen in the figure below:

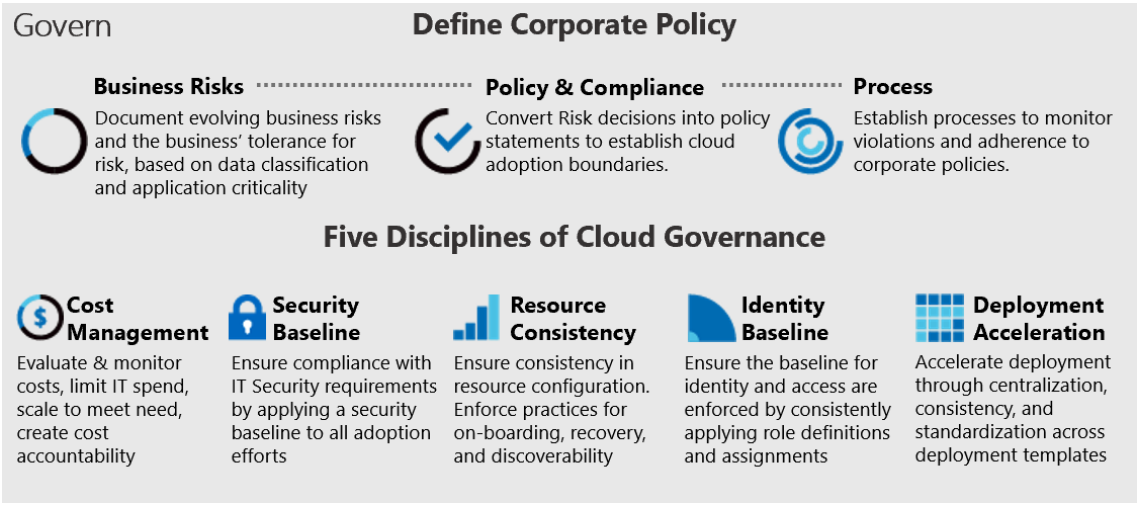


Figure 13. Cloud Adoption Framework Governance Model (Microsoft, 2022a).

As shown in Figure 12, the infographic provides a frame of reference for the end state of Cloud Governance. This should be seen as the potential destination of the Cloud Adoption Framework Governance model. (Microsoft, 2022a.)

Cost Management (in the context of this paper) is one of the disciplines of Cloud Governance and as mentioned this helps to evaluate and monitor costs, limit the IT expenditure and creates cost accountability. For both the enterprises and SMBs, governing the costs is a major concern when adopting cloud technologies. This is also relevant for organizations undergoing any major business transformations like building a cloud strategy, cloud migration etc. The documentation also provides a template for documenting Cost Management discipline. (Microsoft, 2022a.)

Flexera (2021) echoes this approach saying that Cloud Governance remains one of the top challenges for enterprises and SMBs.

There are multiple tools available in the market to provide more details on the Cloud Governance, to identify all the resources, manage their usage, understand the efficiency of the usage and suggest ideas on improving resource utilization and reducing costs. Several organizations have already started adopting the best practices mentioned by the Cloud providers for efficient Cloud Governance. The best practices include (in the context of Cloud Cost Optimization - Governance),

1. Tagging the resources
2. Right Sizing and the SKUs
3. Cloud Reservations
4. Auto-shutdown of the unused instances
5. Decommissioning unwanted resources
6. Auto-Scaling. (Microsoft, Best Practices for Costing and Sizing Resources hosted in Azure, 2022.)

First, *Tagging the resources* – Without proper tags like who created the resource, who should be contacted in case of issues, which department or project the resource belongs to etc., it becomes very difficult for anyone to manage the spend. For example, these resources will be constantly adding to the expenditure but the centralized team or IT might not be aware that the resource can be deleted as the underlying application is no more used.

Second, *Right Sizing* – Although this can be attributed as a developer responsibility, most of the developers are beginners in cloud and they might not be aware of the right sizing for their application. They can create an instance that will be ten times more

packed with memory and other hardware for their simple application and as a result the instance will be under-utilized or idle most of the times during the lifecycle.

Third, *Cloud Reservations* – Reservation Purchases are available in every cloud and offered as a discounted resources by the cloud providers. The principle behind this concept is to offer the users of cloud with resources for a period (usually 1 year or 3 years) an instance or a resource with almost half the actual price for that resource. This promotes cloud usage and cloud adoption while discounting the price. The reservations are available for most cloud resource types. (Microsoft 2022a.)

In relation to Cloud Reservations, a report on the "AWS vs Azure vs GCP: Discounts, Commitments, and Reservations" published on October 13, 2020, provides deep insights into the applicable resource types for reservation purchases and the discounts itself. The report provides information on the discounts, reservations and commitments that can be done on the major public cloud platforms – Azure, Amazon (AWS) and the Google Cloud Platform. The report also summarizes on how to take advantage of the discounts, commitments and reservations in the public clouds by having visibility to multiple clouds and suggests having an agnostic multi-cloud management solution that not only enables to analyze the performance and utilization of the entire multi-cloud infrastructure, but also provides tailored recommendations and automation capabilities.

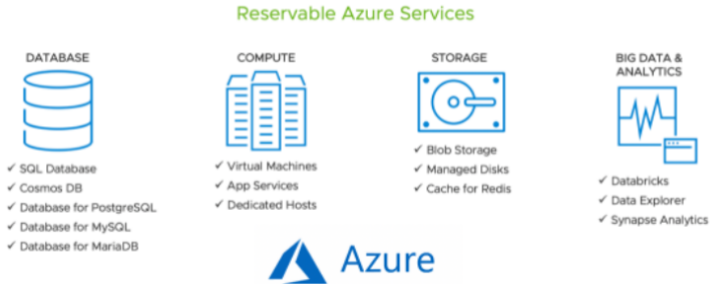


Figure 14. Reservable Services in Azure (VMWare, 2020a).

Figure 15. Reservable Services in Google Cloud Platform (VMWare, 2020a)

Figure 16. Reservable Services in AWS (VMWare, 2020a).

Figures 13, 14, and 15 show multiple services as on 2020 which are reservable or supporting reservations in three major cloud providers AWS, Azure and Google Cloud Platform. The key to taking advantage of discounts and reservations effectively is to use the most appropriate deal wherever available, which often means purchasing reservations from multiple cloud providers (if you're running in multiple clouds).

Fourth, *Auto-shutdown of the unused instances* – Automatically turn-off the resources that are not being used actively or that needs to be run only on scheduled basis. For example, a Virtual machine used only by the developers can be turned off during the after-office hours and the weekend as the development activity will not be mostly happening during this period.

Fifth, *Decommissioning unwanted resources* – There are several resources in cloud and teams while developing might have created certain resources that will be no longer used or needed. These resources need to be identified and properly ramped down.

Six, *Auto-Scaling* – This is one of the most important features in cloud and it enables auto scaling of resources whenever there is demand. For example, during festival times there may be increased sale and as a result there will be increased traffic to the web applications. With Auto-scaling the underlying resources can be automatically scaled up to support the increased traffic and can be automatically scaled down when the traffic is reduced. This reduces the manual effort thus reducing the cost and complexity. (“Best Practices for Costing and Sizing Resources hosted in Azure”, Microsoft, 2022)

Figure 16 from Flexera (2022) describes the rise of the automation policies used by the enterprises to optimize cloud costs.

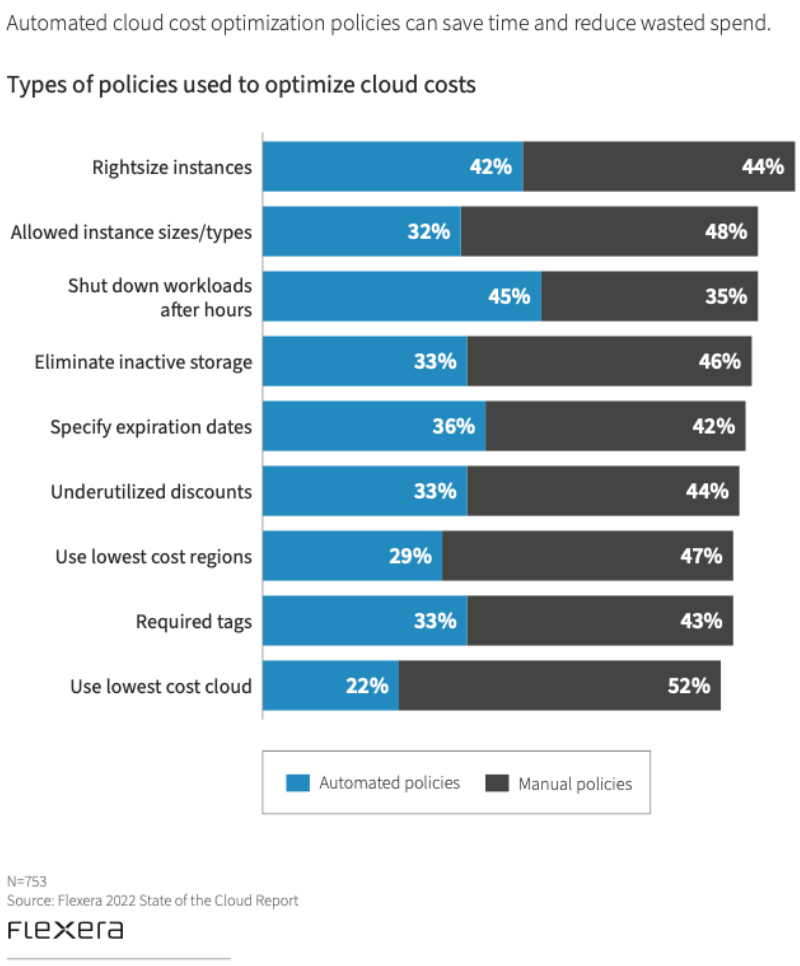


Figure 17. Types of policies used to optimize Cloud costs (Flexera 2022).

Figure 16 shows different types of automation policies used in Organizations to optimize the cloud costs. These policies either enforce or audit the usage of the applicable resources.

Summing up, Cloud Governance uses automation policies in effectively implementing the above use-cases for the purpose of not only optimizing cloud costs but also increasing security which in turn can reduce costs.

4.4 Centralized Team (Cloud Center of Excellence & FinOps)

According to Flexera (2022), organizations are increasingly creating a central cloud team or Cloud Center of Excellence (CCOE) tasked with providing centralized controls, tools and best practices. The purpose of these teams is to accelerate cloud adoption by centralizing expertise while reducing costs and risk. Most organizations (71 percent) have a central cloud team or CCOE. Only eight percent of enterprises and 21 percent of SMBs have no plans for a central cloud team. Figure 17 shows the dynamics of adoption of a central cloud team across organizations.

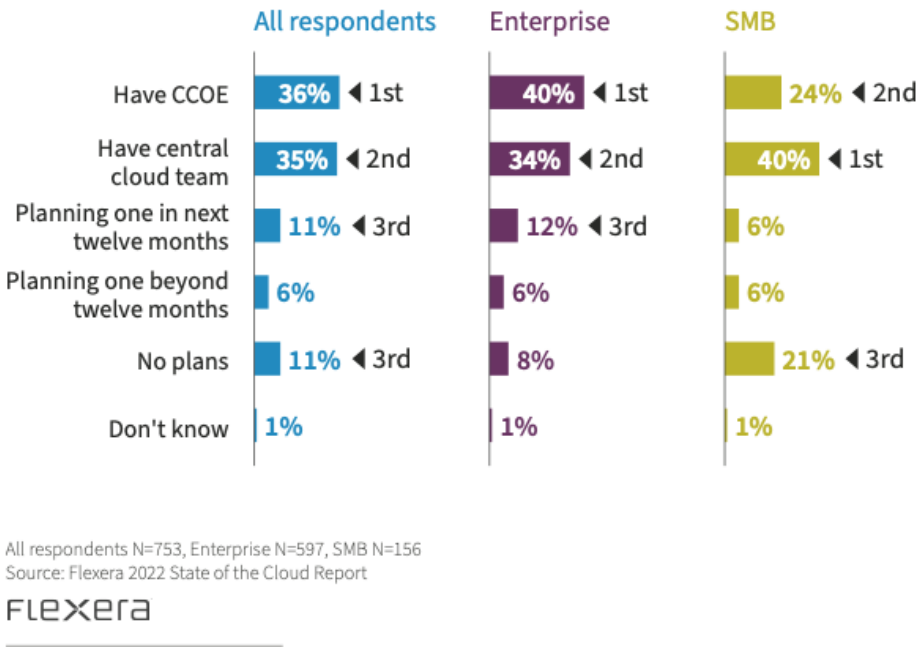


Figure 18. Adoption of Central Cloud Team across organizations (Flexera 2022).

Figure 17 shows that an increasing number of organizations continue to adopt the central cloud team as the reports (Flexera 2022).

A Cloud Center of Excellence is the best practice to drive cloud-enabled transformation. To ensure cloud adoption success, organizations must have the right skills and structure in place. The optimal way to achieve this is by setting up a centralized cloud center of

excellence (CCoE). A CCoE is a centralized governance function for the organization and acts in a consultative role for central IT, business-unit IT and cloud service consumers in the business. Cloud Center of Excellence team is different from traditional IT teams and are not responsible for the actual solution or project or day-to-day operational activities. They act as an enterprise function and are responsible for cloud policy, guiding provider selection, and assisting with solution architecture and workload placement, with the goals of improving outcomes and managing risks. They oversee the organization's cloud computing practices and actively solicit contributions from across the business. The CCoE team provides advisory services to the developers/architects and other technical teams in the organization. (Bernard Feb 26, 2020.)

According to Microsoft (2021), in the Cloud Adoption Framework, the objective of the CCoE is to:

1. Help build a modern IT organization through agile approaches to capture and implement business requirements.
2. Use reusable deployment packages that align with security, compliance, and management policies.
3. Maintain a functional platform in alignment with operational procedures.
4. Review and approve the use of cloud-native tools.
5. Standardize and automate commonly needed platform components and solutions over time. (Microsoft, 2021.)

One of the main responsibilities of the CCoE team is also the Cloud Cost Management. In Organizations which don't have a separate FinOps Team, Cloud cost management is also the responsibility of the CCoE Team. Figure 18 shows the responsibilities on cloud cost management by IT Team and other teams across organizations.

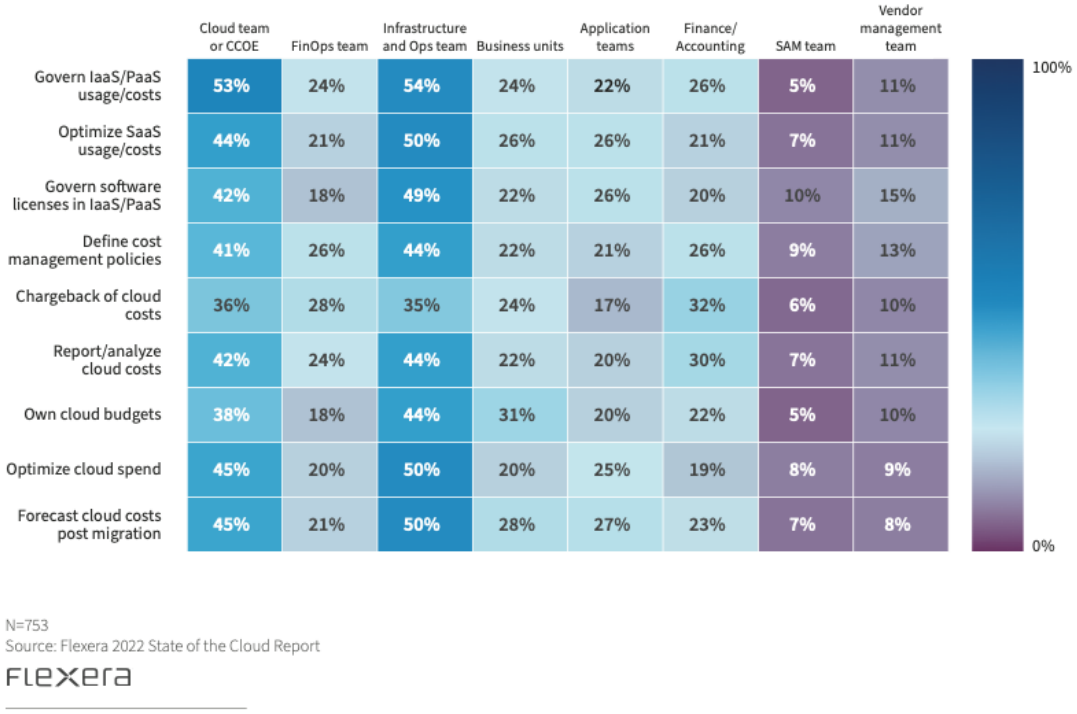


Figure 19. Cloud Cost management responsibilities by IT Team (Flexera 2022).

Figure 18 shows how responsibilities on cloud cost management are distributed in IT Teams and other teams across organizations. This also show the CCOE and FinOps as different teams. The most important roles that can be found in this figure are the Cloud Team or CCoE, FinOps Team and the Infrastructure and Ops Team. While the CCoE team is consisting of cloud architects, Automation experts, DevOps architects and security experts their function is to setup the cloud strategy for the organization. They also report and the analyze the cloud costs along with the FinOps Team. FinOps team main function is the Cloud Financial Management and this team members negotiate with the cloud providers on behalf of the Organization seeking discounts for continuous usage and set the standards for utilizing the reservations that are purchased for an organization. Infrastructure and Ops team consists of developers and operations personnel who develop and support the platform needed for running the application. They play a key role in the cost management as they will be first personnel to deploy and monitor the infra and the policies. They have first-hand experience in controlling the costs.

FinOps - FinOps (Financial Operations) is a framework for managing Operational Expenditures (OPEX). The main function or goal for FinOps Team is to help other teams within an organization to maintain financial accountability for cloud services. The goal of FinOps is to prioritize ongoing optimization of your cloud costs, to make sure

your teams are getting maximum value for minimal spend. FinOps is developed by FinOps foundation.

“FinOps is the practice of bringing financial accountability to the variable spend model of cloud, enabling distributed teams to make business trade-offs between speed, cost, and quality. At its core, FinOps is a cultural practice. It’s the most efficient way in the world for teams to manage their cloud costs, where everyone takes ownership of their cloud usage supported by a central best-practices group. Cross-functional teams work together to enable faster delivery, while at the same time gaining more financial and operational control.” (Storment and Fuller, 2019.)

The discipline of FinOps continues to gain traction in large enterprises. Companies continue to adopt FinOps practices as cloud spend is wasted and optimization remains a priority (Flexera 2022.) FinOps practitioners are from all over the world belonging to different countries. The practice of FinOps is often recognized by some other similar names in different countries. 25% of all the practitioners surveyed recognize this practice as FinOps, whereas 16% of them recognize this as Cloud Financial Management. Some other similar names are also found in some regions such as Cloud Economics, Cost Optimization, etc. In Europe, the overall FinOps practitioners has been growing at a vast speed (currently around 30%) and catching up with the NorthAmerica region, where is the highest (approx. 38%).

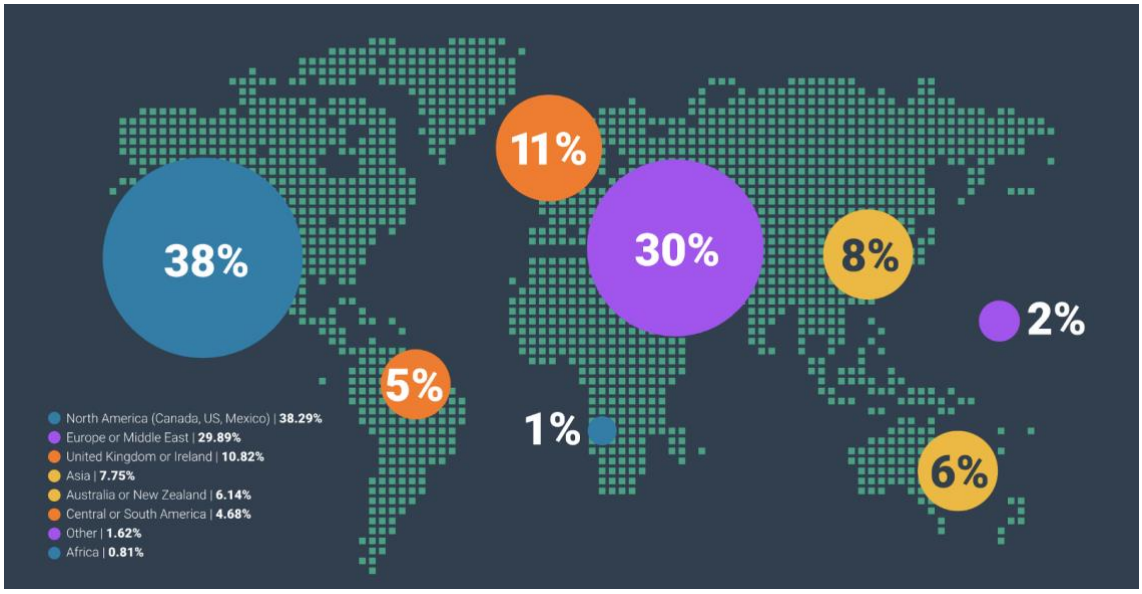


Figure 20. Global spread of FinOps Practitioners (David Amit 2021, FinOps Foundation).

Figure 19 shows the geographic spread of FinOps Practitioners (as of 2021) leading to the growth of FinOps practices across all the regions/continents. As it can be seen from Figure 19, North America and Europe is the highest and in other regions it has been growing constantly.

Summing up, although the Cloud Center of Excellence and the FinOps in certain cases are used interchangeably, Cloud Center of Excellence practices is something that matures into FinOps adoption.

4.5 Conceptual Framework

This thesis focuses on the road to adopt *continuous optimization* of resources in cloud computing services through effective governance, automation and other techniques to the cloud customers. The conceptual framework of this study represents the elements of a successful cloud optimization strategy suggested by literature and best practices, as discussed in Section 4 above in relation to Cloud Governance, Cloud Automation & by establishing the Cloud Center of Excellence (CCoE).

Table 8. Conceptual framework for Cloud Optimization.

Key Steps Towards Cloud Optimization		
1.Automation (DevOps) *Cloud automation* defines the deployment and management of tasks to be automated, and cloud orchestration arranges and coordinates those defined tasks into a unified approach to accomplish intended goals.	***2.Governance in Cloud*** *Cloud governance* provides a set of principles for effective and efficient functioning of the system. Efficient utilization of resources helps in cost reduction & thus enables the organization to achieve its objectives.	***3.Centralized Team*** **(Cloud Center of Excellence & FinOps) - CCoEs** *A cloud center of excellence (CCoE)* is a function that helps organizations balance speed and stability while pursue business and technical agility. CCoEs bring together a diverse group of experts to develop best practice for the rest of the organization. *FinOps* is a framework for managing Operational Expenditures (OPEX). Its main function is to help maintain financial accountability for cloud services (it was developed by FinOps foundation).
Cloud processes that can be automated include: 1) Resource Allocation 2) Multi-cloud Management 3) Infrastructure as Code (IaC) 4) Application Development & Testing 5) Version Control **How to automate the Cloud.** Select the relevant one among	**Strategic organizational steps** to optimize and save cloud costs: *1) make it easier to manage the Cloud Resources:* – Move the multi-tenant workloads in a single account to multiple accounts. – Use various accounts to manage distinct cloud workloads – identify, automate and delete the unused resources.	**Collaboration** is needed between each of the following resources: 1. Cloud adoption (solution architects), 2. Cloud strategy (the program and project managers), 3. Cloud governance, 4. Cloud platform, and 5. Cloud automation. (Microsoft, 2021). Three steps **to establish** an effective **Cloud Center of Excellence** include (VMWare 2020b):

the five existing Cloud Automation approaches: 1) *Ensure full visibility as the foundation for Cloud Automation.* The major cloud platforms offer built-in discovery and visibility capabilities. A cloud management or monitoring platform that offers "single pane of glass" can be used in managing hybrid, multi-cloud, and even multiple subscription/account environments. (Casey 2021, Stockall) 2) *Use Auto-Scaling wherever possible.* Autoscaling can help keep the cloud costs under control by only adding resources when they're needed, whether you use a single cloud or have a hybrid cloud or multi-cloud environment (Casey 2021, Gimenez) 3) *Developer a plan for cost monitoring and optimization.* Cloud spending/ expenditure is one of the main areas that could be benefitted from the automation. The *pay-by-use* billing model, which makes	(It helps to deliver precise access, control, and cost management). (Gill, 2022) *2) curb the shadow IT* (i.e. understand what systems are in use or where corporate data resides). (Gill, 2022) 3) *purchase reservations* – Reservations are the one of the best approaches in controlling the cloud costs. Purchase a reservation license when planning to use an instance for a prolonged period (Annis, Caglio, Caracciolo 2022) 4) *setup a governance process* to handle the reservations that are not utilized (Annis, Caglio, Caracciolo 2022) 5) *create the required framework* to request and access cloud resources quickly. (Gill, 2022) *6)* instead of using spreadsheets or any other manual processes for tracking accounts, cost, and compliance, *set guardrails* to control access, budget, and policy the required projects. (Gill, 2022)	*1. Plan,* i.e. Assess the current state & Define roles and responsibilities. Assess the current state of the organization across finance management, operations, and security and compliance. Define the R&Rs by asking the following questions – • Who should be involved in CCoE? • What should be the strategic outcomes of CCOE? • Where are we today and where do want to be? *2.Build,* i.e. Define the charter and Governance policies. The charter should cover key areas such as Purpose, Goals/Objectives and Responsibilities for the CCoE Team. Defining Governance policies may take time to develop, refine and eventually automate. *3. Run,* i.e. Execute, Measure and Assess. Organizations that have successfully enrolled CCoE offer the following advice: Gain executive sponsorship, Build a community of practice, Don't make CCoE come to you, Provide context in reporting. (VMWare 2020b). **FinOps** The practice of FinOps is inherently iterative and showing maturity of any given process, and/or functional activity. **The FinOps lifecycle** follows the three phases as **a maturity model** (Storment and Fuller 2019).

keeping close track of costs in one or more public clouds an imperative 4) *Use (and automate) resource tagging.* Resource Tagging is one of the key methods of managing classification and ownership, and it's also another where automation is key, perhaps especially in hybrid cloud or multi-cloud environments. (Casey 2021, Stockall) 5) *Build automated, repeatable pipelines (CI/CD Pipelines).* As with infrastructure automation in general, the idea here is to standardize and automate wherever possible – not just in production but *in all phases of the pipeline* (Casey 2021, Stockall)	7) do the necessary *follow-up actions* after receiving an alert. (Gill, 2022)	*1) Crawl Stage Optimization* - reactive, non-invasive actions that require no cultural change like seeking discounts through enterprise agreements or programs, and using commitment for discount tools such as Reservations and Savings Plans. (Peter Shi, Goldiserv n.d.) *2) Walk Stage Optimization* – reactive, invasive actions that requires small amount of cultural change. In addition to the Crawl stage activities, other activites include turning off non-production resources outside of work hours, some process to fit resource size to what's needed (i.e. right-sizing), and general cleanup of unused resources. (Peter Shi, Goldiserv n.d.) *3) Run Stage Optimization* – proactive mechanisms that drive significant cost avoidance and involves lot of trainings, big cultural change. In addition to walk-stage activities, run-stage cost optimization levers may include architectural decisions that balance cost, versus other business/customer requirements, installation of cost anomaly detection systems, use of serverless and spot, application of IT infrastructure automation, and a shift towards open-source and microservices. (Peter Shi, Goldiserv n.d.)

This section defined the conceptual framework of the study. Ideas from literature that were discussed in this section can be used as inputs, along with findings from the current state analysis, to improve the cloud related processes in the case company.

5 Building Proposal for the Roadmap to Cloud Optimization for the Case Company

This section defines and describes the proposal for the Cloud Optimization process and benefits for industries running/building their applications in cloud. For building this proposed solution, the findings from the current state analysis in Section 3 were merged with the conceptual framework from the best practice described in Section 4 and then discussed with the key stakeholders (Data 2), which led to formulating the proposal in Section 5.

5.1 Overview of the Proposal Building Stage

The current state analysis revealed that the case companies A, B & C have the gaps in the optimization process, tools and automation processes and is trying to improve the current standards and practices. The results of Section 3, based on several cases in different technology companies, summarized the need for *Optimization* to be considered as an activity in every phase of the platform/application design and development rather than to be considered as a separate phase which might be too later already. Also, it is evident from the cases that more importance and focus have to be given on developing the *automated* services, *cost optimization* process and initiatives, managing *the governance*, security process and standards, and monitoring of the services.

Therefore, Section 4 searched for literature and best practice in order to find potential ideas focused on the Cost Optimization Initiatives and processes. Section 4 reflected the most relevant best practices such as development of automated services, establishing governance process, formation of centralized team such as a cloud center of excellence to establish standards, promote effective design and development guidelines in cloud, and FinOps teams for managing finance operations.

After revising the previous results, the proposal was conducted in several steps. First, the development of automated services for some of the operational and development activities, governance and adopting DevOps (Continuous Integration and Delivery Pipelines) were analyzed and discussed with the key stakeholders as Element 1 of the Proposal. Second element describes the governance policies that can potentially increase the effective utilization of existing resources, reducing the wastage and utilizing the various cost optimization initiatives/offers provided the cloud providers. Third, establishing centralized teams such as Cloud Center of Excellence (CCoE) and FinOps

teams for guiding and maintaining the financial operations in cloud were discussed as Element 3 of the Proposal. Finally, the initial proposal illustrates the combination of all elements pulled together based on the discussions with the key stakeholders.

The key stakeholders were involved into the process of proposal building. They came up with the suggestions for the proposal, which are discussed in Section 5.2 below.

5.2 Inputs from Stakeholders (Data Collection 2)

The informants or stakeholders were presented with the findings from the current state analysis and the analysis results that pointed to the major area of improvements or the most challenging areas that needs to be revisited or redeveloped. Data 2 collected from key stakeholders was mentioning about the issues with the visibility of cost reporting across all the developers, operations who interact with the cloud services almost every day.

One of the stakeholders was also mentioning about zero visibility to consolidated cost reports except for the resources that a developer would be developing or testing and a view from the developer portal. As stated in the literature (Figure 12, Cloud Adoption Framework Governance Model) Cost Management requires to create a cost accountability, which illustrates the need for creating cost visibility to all the personnel involved in the cloud development & operations. Also, the stakeholder suggested improvements in the alerts that are set for sudden increase in costs like utilizing machine learning or other algorithms to detect sudden surge in the costs and alerting the concerned team and the central team for analysing the actual reasons for the cost increase.

Stakeholder from Company A was also raising challenges like lack of guidance on finding the right sizing or architecture designs that could save cost or optimize cost. The concern or challenge that was that

> "*New Developers or even experienced developers seek to develop solutions that are over-sized, fearing the solution or application could run in to performance issues*".

Literature suggests that Cloud Center of Excellence (CCoE) like teams could provide valid suggestions, best practices, case studies etc.

The stakeholders also suggested ready-made templates (Infra-as-a-code) that could be used by developers to quickly create a test environment via Automation CI/CD pipelines rather than manually developing each time. Manual actions could also lead to error and takes more time.

Stakeholders was also raising challenges with the reservation purchases as not all the reservations can be committed for a longer duration as expected by the Cloud Service Providers.

> *"Reservations are always a cost-saving option, but the cloud service providers expect a longer commitment often 1 year or 3 years and stopping that could attract fines"*

as commented by one of the stakeholders, Respondent 2 . As suggested by literature, Reservations can be bought by the whole organization in a shared subscription and could share the reservation licenses for the whole organization like application A can be using the reservation for 3 months and once not needed the same can be used by Application B or C for the remaining period of the reservation commitment.

The summary of stakeholder inputs is pulled together in Table 9 below, together with the key findings from the current state analysis and a brief summary of ideas gathered from literature and best practice.

Based on these inputs, the proposal draft is pulled together in Section 5.3 below.

Table 9. Key stakeholder suggestions (findings of Data 2) for Proposal building in relation to findings from the CSA (Data 1) and the conceptual framework.

	Key focus area from **CSA** (from **Data 1**)	Input from literature (**CF**)	Suggestions from stakeholders for the Proposal, summary (from **Data 2**)	Description of their suggestion (in detail)
1	Missing Automation & Centralized Team	Manual actions can be reduced to very minimal level with the usage of tools like Terraform (IaC) and CI/CD pipelines. This not only eliminates manual work but also saves a lot of time in making the environment ready for development/testing or production. Also, the templates are incorporated with necessary security configuration to avoid any misconfiguration.	a) Build CI/CD solutions or share the infrastructure as a code (IaC) template to developers, to avoid repeated manual actions for development and testing.	Developers need to spend consistent manual efforts to ramp-up resources that will be used for developing, testing the application or solution. Once development is done, the resources need to be deleted and created again for another development. Also, when doing manually the security configuration might be missed or misconfigured resulting in potential threats. This could be avoided by having ready-made infra as code templates and automation pipelines that could spin-up the needed resources in short time and is also configured with all the needed security configuration
		Application team can be focusing on the application code rather than setting up the necessary infra or networks. Literature suggests about the Landing zone concept and CI/CD DevOps pipelines that promote automation and consistent development.	b) CI/CD Pipelines or Platform Team	For smaller organizations, there might not be a need for a platform team – in that case the automation pipelines should be made accessible for the developers, whereas in mid-sized companies like in case organization A and large organization like in case organization B & C, a central platform team can be given responsibility of the underlying Infra and Security.
		Organizations that successfully establish a cloud center of excellence (CCOE) can cause a significant cultural shift in IT, since	c) Cloud Center of Excellence	There should be a team who can be consulted with or asked for suggestions, best practices, reusing the resources by reducing redundancy etc., As cloud is constantly evolving, it is hard to keep updates with the

		it is a best-practice approach to driving cloud adoption and transformation. The recommendations are to not reinvent the wheel and to use these lessons learned from previous experiences to avoid any pitfalls, avoid the common mistakes, reduce cloud transformation timeline, and reduce overall effort throughout the process		latest options – however a team like CCoE can quickly point out to the guidelines.
2	Cost Optimization	One of the five principles of Cloud Governance is Cost Optimization and as suggested in literature – Cost Management requires to create a cost accountability, which illustrates the need for creating cost visibility to all the personnel involved in the cloud development & operations	a) Cost Accountability, Cost/Spend Visibility	Developers and Operations team should have the accountability of costs incurred on developing and running the solutions in cloud. Cost reports should be visible to the actual developers and operations team and not only to the Managers or higher management who involves mostly in the planning phase
		Budgets as suggested in literature are a measure to keep tap on cost or control costs. The development teams and the operations teams can clearly utilize these automations developed to efficiently utilize the resources and keep a tap on the budgets thus eliminating the unnecessary spend	b) Budgets and Alerts on threshold limits	Budgets control policies (cost limits) should be set on a project for every project/application running in the cloud and the team members including the higher management should be alerted on an increase in the estimated amount.

		FinOps is an evolving cloud financial management discipline and cultural practice that enables organizations to get maximum business value by helping engineering, finance, technology and business teams to collaborate on data-driven spending decisions (FinOps Foundation, 2021)	c) FinOps team	In addition to the budgets, an organizational level FinOps team can be formed to deal with reservations purchases, sharing reservation between projects/applications, establishing channels for purchasing the reservations and for guiding and maintaining the overall financial management/operations

5.3 Proposal Draft

The proposal developed in this study aims to help the case company improve its activities in relation to the cloud optimization strategy drawn from: (a) results from the current state analysis (Data 2) of the three projects cases run by the case company, (b) ideas from literature and best practice discussed in Section 4, and (c) inputs from the stakeholders (Data 2) in relation to running future cloud projects.

The proposal builds on the improvements in the areas of Cloud Governance, Cloud Automation & by establishing the Cloud Center of Excellence (CCoE).

5.3.1 Element 1 of the Proposal: Cloud Automation

According to the stakeholder inputs (from Data 1 and Data 2), the general need for development and operational activities to be more easily and efficiently done demands the development of automated services such as *self-services, automation* of certain development and operational activities. Automation will reduce the manual effort that is needed in monitoring the operational activities, enforcing standards, increasing the effective utilization of resources and make infrastructure or platform ready for development of solutions.

Based on the stakeholder inputs (from Data 1), one of the key issues mentioned was that the development teams were focused on developing the applications/solutions as in on-premises systems rather than *developing the applications/solutions for cloud* i.e., as based on the stakeholder inputs (from Data 2), developing *infrastructure as a code*; also, *security as a code-based solutions* needs to be considered. This will benefit the case company A to a vast extent, as the developers are repeatedly doing manual actions. For the case company B (case company C is also the same), this was already there in parts and as it can be seen, this is already helping them save a lot of manual work. However, this needs to be extended to multiple if not all business groups within the organization. Developing solutions using Infrastructure as a code ensures standard and repeated deployment of the platform such as virtual machines (or other resources such as Cloud Storage, Databases) with all needed configurations, settings necessary to run the applications with clear permissions for the identities. This reduces a lot of manual efforts in setting up the infrastructure or platform in different environment such as Development/Sandbox, QA/UAT & Production.

Also, extending the same development efforts to include *the security as a code,* application as a code development procedure will ensure the necessary security configurations are in place and easily applicable in multiple different environments. This will benefit the case company B, as most of the security configurations are currently manual. The code can be easily stored in a version-controlled repository and made available for the platform team, security team and the application teams in order to further develop the code without interrupting other team's and individual changes and promotes faster development cycle as the code can be reused by multiple teams within the company in different projects and environments.

There are multiple *Continuous Integration and Continuous Deployment (CI & CD) tools* that promote the culture of DevOps (Development and Operations) such as Jenkins, Azure DevOps, GitLab, GitHub etc., that provide the necessary platform for storing the infrastructure as a code, security as a code, application as a code in a central repository and pipelines for testing, deploying the code to cloud. Infrastructure as a code involves writing the entire configuration needed for the deployment of solutions in code that is provided by tools such as Terraform, Chef etc., depending on use case, for example, for development or operational and maintenance activities.

Other activities that need to be done as part of the automation, as understood from the stakeholder inputs (from Data 1), that was evidently missing from the cases in Section 3 include: *visibility across the cloud platform, tagging the resources, setting up and utilizing budgets and auto-scalin*g. Yet, as based on the stakeholder inputs (from Data 2), The development teams and the operations teams can clearly utilize these automations developed to efficiently utilize the resources and keep a tap on the budgets thus eliminating the unnecessary spend. These automations contribute to significant reductions in Cloud Optimization processes.

Thus, pulling all these inputs together, the following steps should be taken in the area of Cloud Automation, Element 1.

Table 10. Summary of the Cloud Automation (approaches, tools and benefits).

No	Processes	Approaches and Tools	Benefits
1	Platform Development, Security & Compliance Configuration	Terraform, Chef, Puppet etc., for development of the code (infrastructure, security & compliance) depending on the use-case	• Platform agnostic • Open source • Modular Portable • Immutable Infrastructure • Reliability • Mapping dependencies • Declarative
2	Application Development (not for Monolithic design, only for modular)	Kubernetes, Containers (application development)	• Compute Scheduling • Horizontal scaling • Self-healing • Automated rollouts & rollbacks • Secrets and configuration management
3	Auto-scaling, Auto-Shutdown	Available as an option in most services like Virtual Machines, Databases etc. and can be enabled during deployment manually or scripting or Infra-as-a-code tools	• Scale up or down depending upon the usage • Shutdown resources when not in use (like weekends for development resources)
4	Resource tagging	Tags & Labels (can be enabled by Scripts, Built in and Custom Policies)	• Identification of resources • Listing or grouping dependencies like Costcenter, Department, Owner etc., • Eliminate orphan resources
5	Cost Control (Budgets)	Setting up Budgets, Alerts (Ex: 50%, 75% of the planned cost) on the Cost/Billing Information (supported by native tools in all cloud providers and can be enabled by scripts, automation and configuration management tools)	• Keeps a tap on the costs incurred • Cost Management

5.3.2 Element 2 of the Proposal: Cloud Governance

Cloud Governance provides the efficient way for controlling and managing the resources needed for the application/solutions. Efficient governance especially on the perspective of cost management increases the visibility of resources available in an organization, eliminate the wastage of resources, utilizing the various benefits offered by the cloud providers. Cloud resources that are setup by the development teams for testing and developing solutions are often forgotten after going-live or deploying applications to production. These resources can be accumulated over time thus increasing the wastage and at certain scenarios can be very difficult to identify whether the resource is needed or not needed for the development team or any other team.

Based on the stakeholder inputs (from Data 2), Cloud Governance can define policies and processes for the users of cloud, to properly tag resources automatically, use of standard resources (not allowing the creation of high-cost resources without proper approvals or letting the developer understand that they aren't creating these resources by accident or casually), delete and remove unused resources when not needed. They also provide options for alerting when a resource is not used for a period or needs to be deleted and the teams are notified for actions on the same.

Moreover, organizations where multi-cloud or multiple customers are involved, the governance policies can set up the standards such as managing multiple customers in separate/isolated tenants, subscriptions/accounts/projects rather than having a single account/project in a tenant. This will ensure isolation of workloads for multiple customers and eliminates the risk of data exposure to not needed identities and increases managing the workloads meant for different customers.

Cloud Governance will also establish a framework for purchasing the reservations (an option provided by the cloud providers for purchasing resources at much reduced prices depending on long-term usage needs), utilizing the reservations purchased, monitoring the usage and control over the non-utilization of reservations.

Thus, pulling all these inputs together, the following steps should be taken in the area of Cloud Governance targeting Cost Optimization, Element 2.

Table 11. Summary of the Cloud Governance (approaches and benefits targeting Cost Optimization)

No	Processes	Tools	Benefits
1	Multi-Cloud Governance – Establishing Standard, Policies	Azure Management Tools, Flexera Cloud Management, Cloudify, Terraform Enterprise, ServiceNow IT Operations Management etc., (Gartner, 2022) (or) custom tools built on python or any other language	• Isolation of Customers • Avoid Potential data exposures • Effective management of distinct workloads
2	Purchasing and Managing Reservations	Same as above (and/or) Individual cloud platforms AWS, Azure and GCP	• Run applicable resources at reduced cost (< 50% of the original cost depending upon the usage scenarios)
3	Policies for cost control, compliance	Same as above (and/or) Custom and Built-In Policies in Azure, AWS and Google Cloud, Setting Budgets for Accounts, Subscriptions and Projects in AWS, Azure and GCP respectively, Cloud-Native tools in respective clouds	• Ensures high-cost resources are not created by accident or casually • Limiting the resource creation beyond budgets • All necessary security and compliance is in place (like policies for NSA, GDPR compliance etc.,)
4	Cost Reporting across all Clouds, Resources	Reporting in PowerBI (or) individual Visualization Tools in respective Cloud Platforms	• Export all cost incurred in respective clouds to a central database and report the data in PowerBI • Ensures visibility of all the cloud costs including drill-down details available in single place • Enables monitoring of the reports rather than monitoring in individual clouds

5.3.3 Element 3 of the Proposal: Centralized Team - Cloud Centre of Excellence (CCoE)

Traditionally the application development teams will contact the central IT teams who manages the procurement, installation and maintenance of the platform needed. There can be multiple teams within the IT such as Networking, firewall but collectively called as IT and have full visibility and control of all the infrastructure needed for the applications. However, in cloud the situation is changed as resources needed for running an application can be automatically built by the decentralized application teams in addition to managing the network and firewall policies with necessary access. This adds challenges in managing the configurations that ensures security, network and firewall controls. The option is not to go-back to the centralized IT team but to ensure centralized teams have necessary control and management of resources.

Based on the stakeholder inputs (from Data 2), a centralized team setup in large organizations like the case company B & C, will introduce development, guidance and support needed for the multiple application developers/teams and will help in eliminating non-standard developments. Figure 20 shows the structure that his centralized team could have.

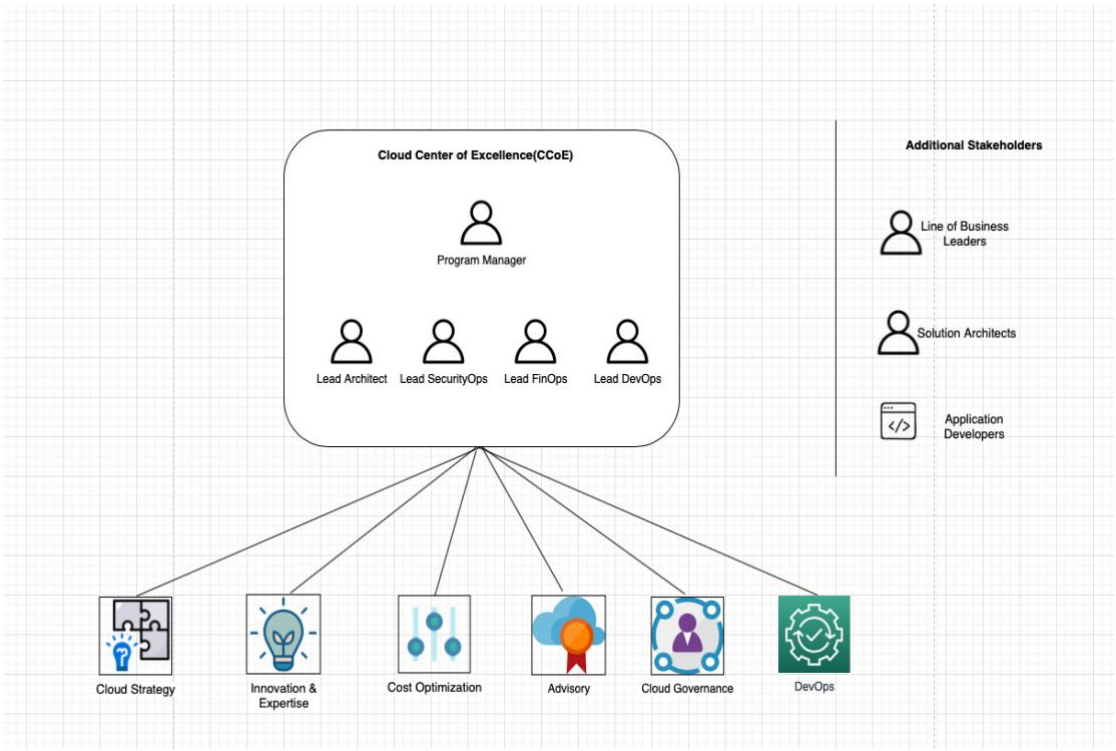


Figure 21. Cloud Center of Excellence team and its functions.

Figure 20 illustrates the Cloud Center of Excellence team and its functions. A Central Cloud Center of Excellence (CCoE) team can bring in the necessary standards, provide guidance etc., for other teams working in the cloud. The CCoE team is not the IT team and is not responsible for the resources themselves but serves as an advisory and provides the necessary tools and guidance. The main function of the CCoE is to support governing and guarding the execution of Organization's Cloud Strategy. The CCoE team should be a cross-functional team with experts from different fields of expertise – Financial, Security, Design & Architect, Develop, R&D, DevOps etc., and should be able to provide valuable inputs to the actual developers.

Moreover, based on the stakeholder inputs (from Data 2), in some cases depending on the organization's size of deployment of services in cloud and expenditure incurred in cloud, it is good to have a FinOps team. The FinOps team will be then responsible for the cloud expenditure control, purchasing of reservations, credits from the cloud service providers, monitor the usage of reservations, high-cost resources, providing cost visibility to C-level executives, directors and department heads too. The FinOps can also be part of the CCoE and provides documentation or guidelines and sets standards for the consumption of reservation purchases and budget controls etc., FinOps team can work with lead architects as part of the CCoE Team and can introduce cost optimization initiatives and code that can be utilized by actual application development teams. FinOps team can work with DevOps teams in promoting the usage of cloud native architecture and design principles in development of applications.

5.4 Initial Proposal: Summary

The initial proposal was pulled together from the elements described above, namely from:

- Element 1 - Cloud Automation,
- Element 2 – Cloud Governance,
- Element 3 – Centralized Team - Cloud Centre of Excellence (CCoE),

all these elements merged and guided by the Conceptual framework of this study.

Based on these inputs, Figure 21 below pulls together the proposal for **the Roadmap for Cloud Optimization.**

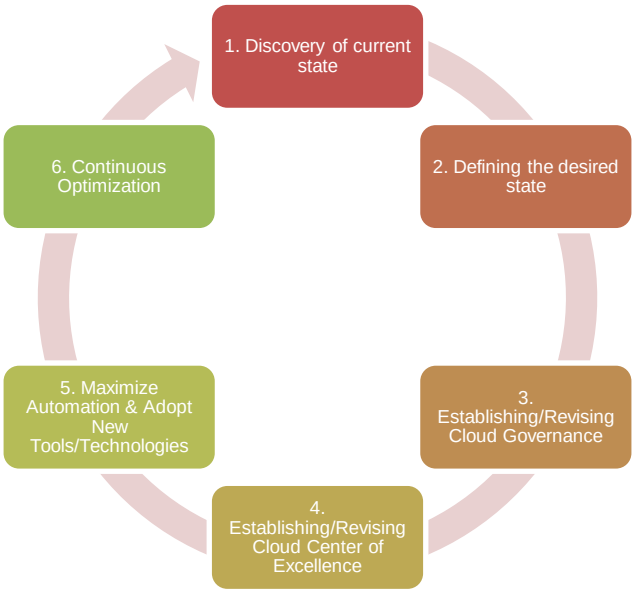


Figure 22. Initial Roadmap for Cloud Optimization via Governance.

Figure 21 is opened up in a step by step manner in Table 12 below.

Table 12. Initial Roadmap for Cloud Optimization via Governance.

STEP 1. Discovery of the Current state
1. All the case organizations should perform analysis of their current state. This must be done periodically and not a one-time action. 2. The analysis should include a. Expenditure incurred, b. Visibility of resources, cost, budgets to developers, end-users, c. Current Governance framework, policies, d. Teams involved in the Cloud Migration, Cloud Development and Operations e. Applications running in Cloud and their architecture, performance, cost etc., f. Existing process for Cloud Onboarding, seeking Guidance, availability of Standards & procedures

3. The analysis should be done with the help of all the teams involved in the cloud development and operations. 4. Analysis results can/should be published as reports shared with all the teams 5. Develop automation wherever possible for performing the analysis as, this activity needs to be repeated 6. Tools needed for collecting, monitoring and reporting the measurements should be in place
STEP 2. Defining the desired state
7. All the case organizations should perform analysis of their current state. This must be done periodically and not a one-time action. 8. The analysis should include a. Expenditure incurred, b. Visibility of resources, cost, budgets to developers, end-users, c. Current Governance framework, policies, d. Teams involved in the Cloud Migration, Cloud Development and Operations e. Applications running in Cloud and their architecture, performance, cost etc., f. Existing process for Cloud Onboarding, seeking Guidance, availability of Standards & procedures 9. The analysis should be done with the help of all the teams involved in the cloud development and operations.
STEP 3. Establishing/Revising Cloud Governance
10. List all the existing governance policies including policies for a. Security & Compliance, b. Cost Reporting and Budget Controls, c. Reservation Purchases

11. Revisit the existing process for handling reservations and understanding the gaps involved 12. Introduce and make it easy for the development teams to utilize the reservation purchases by creating a framework for reservation purchases 13. Limit the number of resources not using the reservations to minimum and establish process for easy onboarding 14. Ensure all the accounts are isolated from each other through strict IAM policies 15. Ensure all the projects/applications running on cloud have a budget limit and necessary alerts configured when crossing the thresholds. 16. Periodically revise all the security policies and controls with the cloud best practices and information published by the cloud service providers 17. Check with the organization's Security & Compliance team on any new updates for the security configuration, data compliance guidelines and publish this information to all Cloud Development & Operations Teams.
STEP 4. Establishing/Revising Cloud Center of Excellence
18. Formation of Cloud Center of Excellence (CCoE) team by involving right set of Cloud Architects, FinOps, Network Experts, DevOps Experts, Security & Compliance Experts 19. The CCoE team don't need to be a separate team or division but can be formed by including the experts across various fields as mentioned above 20. The CCoE team should serve as a guidance team within the organization – should be publishing best practices, case-studies of previous migration, application development, cloud native development, lessons learnt etc., 21. The core function for the CCoE team is to establish standards and provide help & guidance on the architects, reusing existing infrastructure etc., However, the team shouldn't be used for actual development of an application in cloud or cloud migration 22. If the CCoE team is already established, ensure proper Roles and Responsibilities of the CCoE team as defined in the literature and by identifying the gaps in the CSA.

23. In large companies like in Case A and B, separate platform team can be created for setting up the foundations and application teams can be responsible only for the application development and maintenance. 24. A separate FinOps team can be formed based on the company size and the expenditure incurred in the cloud.
STEP 5. Maximizing Automation and Adopting New Tools & Technologies
25. Manual efforts should be eliminated as high as possible, and automation should be promoted. 26. Teams building automated deployments can be encouraged and provided with adequate support from the CCoE Team 27. Events can be conducted to promote automation. 28. The code used for automation can be shared with multiple teams within the organization for reuse and enhancements. 29. All the policies defined in the governance should be automatically applied across all the accounts in all the clouds. 30. All applicable resources should make use of the automatic scaling options and shutdown options provided by the Cloud Service Providers.
STEP 6. Continuous Optimization
31. Organization should ensure review and revising the steps followed for Cloud Optimization based on recent developments in the Cloud Technology and their Organizational strategy. 32. All steps in the roadmap are continuous initiatives and can be enhanced or modified depending on the changing needs. 33. Depending on the target and desired states, current measure - a timely revision should take place.

As seen from Table 12, the goal of this proposal was to develop the Roadmap to achieve Cloud Optimization for the case organizations A and B and view the benefits provided by Optimization. Such a roadmap should help the case organization A & B (a) to achieve more visibility on the costs and ensure accountability from the actual developers/operations personnel, (b) help the developers to recognize the benefits of

sharing resources, seeking guidance and learning from case-studies, reusing codes and automation pipelines to avoid manual actions, as well as (c) for the security personnel to ensure all the security and compliance standards are by default followed in the cloud via Automation (d) for the decision-makers, to recognize the gaps in the current processes, solutions and tools, and thus help decide on the direction for further actions to develop optimization.

Next, Section 6 continues the discussions on the proposed elements and validates them into the Final proposal.

6 Validation of the Proposal

This section reports on the results of the validation stage and the recommendations for further developments to the initial Proposal. First, the sections describe how validation was conducted. Next, it discusses the developments to Initial proposal. At the end of this section, the Final proposal and the recommendations are presented.

6.1 Overview of the Validation Stage

This section validates the proposal developed in Section 5. The validation was provided by the key stakeholders involved and the expert judgement was also received from Cloud Consultants working with the case companies. Validation was also done in parts i.e., the current and desired state for Governance and Automation was carried out and the respective phases were also started. In the case companies B & C, as this was a large company this did work well rather than to follow step-by-step process and in identifying who is responsible for what.

The validation was presented for the experts who are part of the Platform teams in the case organization for their feedback on the proposal. This feedback was very important for this study, because it provided the professional view on the thesis objective and outcome. The validation was also shared with the respondent 1 from Case Organization A and the feedback was received. The experts were asked to share their feedback on the proposed ways, their inputs on what can be modified and how to implement, measure the proposed methods.

Testing or Pilot implementation of the proposal with few modifications was also performed by Respondent 3 in the case company as part of the Case Project C. The pilot implementation included documenting the current state and defining the target state for two of the phases – Establishing Governance and Maximizing Automation. This approach was selected because other than for the above-mentioned phases, other phases would require involvement from multiple teams and business groups in Case companies B & C.

Based on the feedback and the insights gained from the two validation scenarios, the final proposal is created. The Final proposal includes the revised and updated information about the topic of the study.

6.2 Developments to the Proposal (based on Data Collection 3)

This sub-section reflects on the improvements of the Initial proposal gathered at the validation stage (Data 3). This Data was gathered from the key stakeholders in the form of opinions, validation comments, and recommendations to the Initial proposal and concentrated on identifying development points proposed by the experts.

Table 13. Expert suggestions (findings of Data 3) for the Initial proposal.

	Element 1 of the Initial proposal	*Parts commented in Validation*	*Description of the comment/ feedback by experts (in detail)*	*Development to the Initial proposal*
1	Automation based on Infrastructure as a Code, Security Configuration as a Code, Application as a Code and Automating creation of Budgets, Scaling Up/Down the unused resources and ensuring proper tagging of resources	a) Application Moderning & Application as a Code	The experts provided feedback that not all the applications can be modernized and wherever it is possible infrastructure as a code can be made available in an artifactory for use by multiple teams. This will ensure reuse and enhancements of the code and reduce developing everything from the scratch.	A git-based repository or artifactory can be established and multiple teams can share the actual infra as a code with the platform team acting us moderator.
		b) Tagging of resources	The experts suggested needs for ways to identify tagging and ensure correct tags are in place. With incorrect tagging, the cost can be distributed elsewhere.	Automatic alerts need to be developed to ensure when critical tags are modified and is validated against the desired configuration
	Element 2 of the Initial proposal	*Parts commented in Validation*	*Description of the comment/ feedback by experts (in detail)*	*Development to the Initial proposal*

2	Establishing Standard, Policies, Policies for cost control and compliance	Multi-Cloud Governance with a single tool may results in higher data egress costs	Collecting data from different clouds in a single place may result in data egress charges that can be higher if not carefully planned for.	Minimize the data being collected. Also, check for balance between cost incurred for data collection vs tool support & cost.
	Element 3 of the Initial proposal	*Parts commented in Validation*	*Description of the comment/ feedback by experts (in detail)*	*Development to the Initial proposal*
3	Cloud Center of Excellence – Multiple Teams – Roles and Responsibilities	Platform Team, FinOps Team, Cloud Center of Excellence	The roles and responsibilities of the proposed multiple different teams needs to be clearly defined. Scenarios where the three teams will be needed needs to be addressed to. It might not be that responsibilities are overshadowed or left for other teams i.e., Platform team might think this is not their responsibility but Cloud Center of Excellence and vice-versa.	Not all organizations need three different team as proposed. Depending upon the scale of the organization this can be changed. In mid-level organizations, it might be possible that platform team can also serve best practices and act as Cloud Center of Excellence.

As seen in Table 13, the stakeholders and the expert provided their feedback on all the three elements of the proposal with suggestions for improvements in the proposed elements. Also, as general feedback from one of the stakeholders was to enable each different stage as an independent stage and adopting the first two stages – measuring the current state and defining the desired state as a pre-cursor for every stage. The idea was to use the Agile approach (combining both iterative and incremental) instead of the proposed approach. This way the desired state can be defined (what the company really needs), the steps need to improve the current state to desired state will be incrementally developed and delivered. Based on the perceived benefits, the process and the automation or the steps can be improved further in the next iteration moving closer to the target goal in every iteration.

6.3 Final Proposal

This sub-section rounds up the Final proposal, which is produced from the combination of Section 5 Initial proposal and Section 6 Recommendations for improvements. The Final proposal is important finding for the case organizations due to its wish to be the one the most digitally developed company and enable digital transformation for its clients. As was mentioned before, the case company has the gaps in the optimization, automation and governance sections as a result of several teams or not clearly defined roles and responsibilities. The developers must spend more time in learning and understanding key technologies before working with the actual application. There was no central platform team or automated pipeline for setting up the necessary infrastructure like connectivity, governance, security in cloud and the application team doesn't have the required expertise or knowledge in configuring these.

The company can utilize the study's material, the theoretical knowledge and the final proposal for the future development of roadmap to cloud optimization. It is wise to further develop the risk analysis from applying certain elements mentioned in the proposal like switching to Infrastructure as a code etc. The risk analysis could involve the investigation how the outcomes and the objectives can change because of the impact of risk possibility. After identifying the risks, they need to be analyzed in order to successfully create steps to mitigate these risks. Also, the financial part of the final proposal could be developed. Although the study proposed use of multiple different tools, the case companies should analyze the risk and value before zeroing on a digital tool or technique. When choosing a particular digital solution, the customer desires to understand not only the digital value, but also the financial value from utilizing the tool. Therefore, the further development of the Final proposal will enhance the case organization's chances to create a roadmap for the cloud optimization, optimize the resource spend and pay way for effective utilization of the cloud resources.

The final proposal is to use Step 1, step 2 and other steps not sequentially but can be adopted independently as below:

The final proposal is to use Step 1, step 2 and other steps not sequentially but as individual pillars that can be adopted independently as below and follow the agile development approach for the adopting the cloud optimization roadmap:

The agile approach will ensure the desired state will be defined and the benefits can be realized in a faster way (incrementally) while developing the steps mentioned in the roadmap. This will also ensure that the benefits if it can be improved further will be developed during the next iteration. There can be certain actions that can be repeated in multiple pillars but nevertheless it can be skipped if the actions are already taken care. Also, while implementing or testing every stage, the benefits need to be measured and financial value should also be calculated. This will allow the case organization to realize the savings in the financial terms. As already mentioned in the initial proposal, the tools & techniques will be changing and so the processes need to be changed according to the adopted tools & techniques.

7 Conclusion

This section contains the summary of this study. The executive summary describes the main steps and results of the study. Then, there are proposed next steps towards implementation. Finally, the research quality and thesis evaluation are discussed.

7.1 Executive Summary

Digital Transformation is no more the future but the present. Digital Transformation takes the customer-driven, digital first approach to all aspects of the business. Digital Transformation uses Artificial Intelligence, Cloud Technologies – Hybrid & Public Cloud, and other digital technologies to leverage data and drive intelligent workflows, faster and smart decision making and real-time response to market disruptions. Cloud Computing became the vital or most important part of the Digital Transformation. Any organization that wants to future-proof its operations and reach the digital transformation goals must take cloud-first approach. However, Cloud Computing if not planned correctly, can result in huge cost impact to an organization’s operations. Onboarding to Cloud or adopting Cloud and Cloud Migration is mostly a one-time action and often involves very less Capital Expenditures like getting an expert to work on the technologies or involving consultants. However, the Operational Costs in the cloud can reach surprisingly high costs if not planned carefully and Cloud Optimization is not adopted.

The objective of this study was to provide a Roadmap for Optimizing the Cloud Costs mainly the Operational Costs and discuss various options including how to measure the

current state of an organization, defining the desired state, different aspects of optimization etc., The main goal was to identify the areas that impact the Cloud costs, the impact and ways to overcome these. The scope of this study was limited to case companies – Mid and Large Organizations. The outcome was the identification, description of areas for Cloud Optimization and roadmap for adopting cloud optimization.

The study followed the multiple case study approach. In this study, three case projects were chosen to be investigated. The data was collected in three rounds. The first round, Data 1, was gathered for the current state analysis by exploring publicly available documents, conducting meetings with current employees, external consultants of the organization who had worked in the case projects. Data 2 was gathered from meetings, interviews, internal documentation and was applied in the Proposal building. Data 3 was gathered from the interviews, actual work experience and internal documents for validation of the Initial proposal.

Both, the insights from the current state analysis together with ideas from literature and best practice paved the way for building the proposal. The proposal was merged out of several elements. First, Element 1 derived ideas on what could be automated and how, and the benefits of the automation. Second, Element 2 analyzed ideas on effective governance, establishing the process for reservations, visualizing cost of resources and ensuring compliance. Third, Element 3 revised the role of Cloud Center of Excellence (CCoE) and how it can support governing and guarding the execution of Organization's strategy. Additionally, the researcher also zoomed into the literature, for inputs on how effective the Cloud Cost Optimization programs can be achieved in large and mid-sized organizations. Based on this input, and supported by the co-creation discussions with the stakeholders, the initial proposal was built.

The proposal suggested to build a roadmap for the cloud optimization by focusing on the three elements – Cloud Automation, Cloud Governance and Cloud Center of Excellence. It was also recommended to have a roadmap for cloud optimization before starting or during the initial stages of the cloud migration. This will enable easier adoption of tools, techniques and processes. The current and desired state needs to be measured and defined before implementing or testing each element suggested by the proposal. Also, it was proposed to test the elements and measure the outcome, as it was done for the Case Project C. It can be witnessed in the Case Project C, the roles and responsibilities are already split and clear between the platform and the application teams. Also, the platform was created/managed using Automated Pipelines that enabled the platform

team to deliver faster setup, which can help the application team to focus only on the application. For the case company A, the platform team can be simply replaced by an automated CI/CD pipeline with inbuilt testing. This will enable less efforts and time needed for the migration and after the migration the resources are effectively utilized and governed. Cloud Center of Excellence serves as a custodian of Organization's overall cloud strategy and helps multiple teams in following best-practices and knowledge sharing.

This initial proposal was validated in with the key stakeholders where further ideas and recommendations were gathered how to improve this proposal. The expert judgement was provided in a professional and constructive way that enabled further developments in the proposal. In the final proposal, the thesis demonstrates that the main benefits of adopting roadmap for cloud optimization relate to an efficiency increase, reduction and control over the operational expenditure, and adhering to security & compliance. Indeed, there are many other benefits, such as faster delivery to market, focusing on the application workload by developers, ensuring the operational costs are spent appropriately and planning for the future.

7.2 Managerial Implications (Next Steps and Recommendations toward Implementation)

The case organization B & C's ambition is to become market leader in the digital technologies and case organization A also has similar ambition in their respective field. Both the case organizations follow cloud-first approach when considering their workloads. By pioneering in this field, the companies can enable its clients to take advantage of leading industry practices including Big Data, Artificial Intelligence and Internet of Things.

Approach or steps towards the final implementation of the proposal can be considered as follows:

First, the suggested benefits of adopting roadmap for cloud cost optimization can be published in the organization's internal newsletters and employees can be introduced to the benefits of the optimization. It is important that the employees should have a visibility of the operational costs that is being spent by the companies, so that the workforce is better aware of the need and benefits of potential savings.

Second, I would recommend analyzing the current situation based on the elements mentioned in the final proposal – tools and techniques being used, existing processes and feedback from multiple teams who are working with cloud technologies. The feedback should provide an insight of, “What works well?”, “What/Where is the bottleneck?”, “Can the process be streamlined further?”, “What can be made better or improved?”, “does the operations and development teams get adequate support?” etc.,

Third the desired state of the organization as mentioned in the final proposal could be developed. Areas that require changes as cited in the proposal, roles and responsibilities, processes and tools and techniques can be defined. The desired state should be having a clear definition of what needs to be achieved in each areas – Automation, Governance, Center of Excellence.

Fourth, the actual steps as described in the roadmap can be followed to bridge the gap between the current and the desired state needs to be implemented/tested on a pilot basis, maybe in a single team or multiple of teams. This allows quick measurement of the pilot tests and there could be further improvements to the implementation based on the outcome. The benefits and the outcome can serve as an onboarding guide for other teams within the organization to adopt the roadmap. In my opinion, in case companies like B & C, it is better to have the roadmap adopted by multiple independent teams and once the benefits are realized, it could be published to all the teams. As mentioned in the final proposal, the measurement of the outcome and continuous improvement should be done.

Finally, all the steps in the roadmap are continuous initiatives and can be enhanced or modified depending on the changing needs. Depending on the target and desired states, current measure - a timely revision should take place. This will ensure that the case companies realize the cost optimization benefits in a sustained manner.

7.3 Thesis Evaluation

The study was significant for the case organizations as the organizations have adopted the digital transformation and a cloud-first approach. Since the case organizations have a cloud-first approach, it is important to improve the optimization and set the standards for a cloud-driven transformation. By adopting the roadmap for cloud optimization, the

organizations can reap the benefits of cloud computing while minimizing the operational expenditure.

The objective of this study was to identify the elements or areas in the cloud computing which if not carefully controlled can spiral the costs incurred. The study outcome meets the above objective and therefore identifies and describes the roadmap to cloud optimization and the benefits. The study didn't discuss in depth or more detailed level on the Application Modernization, but this can be a different study all together because of the different type (nature) of Applications available and the complexity involved. Also, the main objective of this study was to present a roadmap for overall Cloud Cost Optimization while briefly discussing about various components involved. The study also discussed about the various tools and third-party products available and how to avoid vendor lock-in but the decision to use a particular tool still rests with the organization.

The Final proposal, which is produced from the combination of Section 5 Initial proposal and Section 6 Recommendations for improvements. As mentioned earlier, the final proposal is to use Step 1, Step 2 and other steps not sequentially but can be adopted independently. Step 1 and Step 2 can be the initial actions for every other stage. All the rest of the stages can be acted upon independently. There can be certain actions that can be repeated in multiple stages but nevertheless it can be skipped if the actions are already taken care of. Also, while implementing or testing every stage, the benefits need to be measured and financial value should also be calculated. This will allow the case organization to realize the savings in the financial terms.

The case company can utilize the study's material, the theoretical knowledge and the final proposal for the future development of roadmap to cloud optimization. In my opinion, it would be wise to further develop the risk analysis from applying certain elements mentioned in the proposal like switching to Infrastructure as a code etc. The risk analysis could involve the investigation how the outcomes and the objectives can change because of the impact of risk possibility. After identifying the risks, they need to be analysed in order to successfully create steps to mitigate these risks. Also, the financial part of the final proposal could be developed. Although the study proposed use of multiple different tools, the case companies should analyze the risk and value before zeroing on a digital tool or technique. When choosing a particular digital solution, the customer desires to understand not only the digital value, but also the financial value from utilizing the tool. The tools & techniques will be changing and so the processes needs to be changed according to the adopted tools & techniques. The proposed

approach should enhance the case organization's chances for effective cloud optimization, optimizing their resource spend, and thus paying way for effective utilization of the cloud resources.

7.4 Closing Words

Digitalization is driving all industries nowadays. Every industry irrespective of the core function relies on the digital tools and processes to improve the product availability, quality and faster delivery to the market. Cloud Computing is at the core of the digital transformation. Cloud computing enables companies to reduce capital expenditure and drives the digital transformation faster to achieve effective results but can easily increase the operational expenditure if not done carefully. This study proposes to utilize the cloud computing in an efficient and effective way by adopting roadmap for cloud cost optimization. Because the use of cloud computing enhances the digital transformation, thus, it generates more value, boosted profitability and greater opportunities for the companies applying it.

References

Amit, D. (2021), “FinOps Adoption as an Evolutionary Process” (17.03.2021). Available at https://www.globaldots.com/resources/blog/finops-adoption-as-an-evolutionary-process/ Accessed: May 2022

Annis, P. E., Caglio, G., and Caracciolo, M. B. (2022). “The Road to Azure Cost Governance”. (February 2022). Packt Publishing.

Babla, D. (2019), "Challenges In Managing Cloud Costs & Its Proactive Solutions". Available at: https://www.linkedin.com/pulse/challenges-managing-cloud-costs-its-proactive-solutions-disha-babla Accessed: March 2022

Bernard, A. (2020). “The Ultimate Cloud Center of Excellence (CCoE) Framework”. (February 26, 2020). Available at: https://www.apptio.com/blog/ultimate-cloud-center-excellence-ccoe-framework/ Accessed: March 2022.

Bird, J. (2016). “DevOpsSec”. (June 2016). O’Reilly Media, Inc.

Casey, K. (2021) “5 approaches to Cloud Automation”. (4 February 2021). Available at https://enterprisersproject.com/article/2021/2/cloud-automation-5-approaches Accessed: March 2022

FinOps Foundation (2021), “Cloud FinOps Definition”, Available at: (https://www.finops.org/introduction/what-is-finops Accessed: July 2022

Gartner (2022), “Cloud Management Tooling Reviews and Ratings: Products in Cloud Management Tooling Market”. (2022), Available at: https://www.gartner.com/reviews/market/cloud-management-tooling Accessed: July 2022

Hall, T. (2022). DevOps Best Practices. Atlassian, Software Development. Available at: https://www.atlassian.com/devops/what-is-devops/devops-best-practices Accessed: March 2022.

Harvey, N. (2016). “2016 All Day DevOps Conference”, alldaydevops.com Available at: https://devops.com/modern-infrastructure-automation Accessed: March 2022.

Imperva (n.d.), “Cloud Governance”. Available at: https://www.imperva.com/learn/data-security/cloud-governance/ Accessed: March 2022

Microsoft (2021), “Cloud Center of Excellence (CCoE) functions”, Microsoft Docs (09/30/2021) Available at: (https://docs.microsoft.com/en-us/azure/cloud-adoption-framework/organize/cloud-center-of-excellence) Accessed: March 2022

Microsoft (2022a), “Best Practices for Costing and Sizing Resources hosted in Azure”, Microsoft Docs. (2 April 2022). Available at: (https://docs.microsoft.com/en-us/azure/cloud-adoption-framework/govern/cost-management/best-practices) Accessed: March 2022

Microsoft (2022b), “Govern Methodology for the Cloud”, Microsoft Docs (02.08.2022) Available at: (https://docs.microsoft.com/en-us/azure/cloud-adoption-framework/govern/methodology) Accessed: March 2022

Rice, J. and Matlin, A. (2021). “Our Journey towards cloud efficiency”. Airbnb, April 6, 2021. Available at: https://medium.com/airbnb-engineering/our-journey-towards-cloud-efficiency-9c02ba04ade8 Accessed: March 2022.

Sabharwal, N., Pandey, S. and Pandey, P. (2021). “Infrastructure-as-Code Automation using Terraform, Packer, Vault, Nomad and Consul”. (24 August 2021). Apress Berkeley, CA.

Sabharwal, N. and Pandey, P. (2021). “Pro Google Cloud Automation”. Apress Berkeley, CA.

Shi, P. (n.d.), “When Do Cloud Savings Start to Kick in ?” FinOps Foundation. Available at https://www.finops.org/stories/when-do-cloud-savings-kick-in/ Accessed: May 2022

Singh Gill, N. (2022). "Cloud Governance Challenges and Best Practices". (19 May 2022). Available at https://www.xenonstack.com/blog/cloud-governance Accessed: May 2022

Storment, J.R. and Fuller, M. (2019). "Cloud FinOps". (December 2019). O'Reilly Media.

VMWare (2020a), "Cloud Health by VMWare Suite Staff: AWS vs Azure vs GCP: Discounts, Commitments, and Reservations". (October 13, 2020), Available at: (https://blogs.vmware.com/cloudhealth/aws-vs-azure-vs-gcp-reservations-pricing-discounts/) Accessed: March 2022

VMWare (2020b), "Cloud Health by VMWare Suite Staff: 3 Steps to Establish an Effective Cloud Center of Excellence". (October 19, 2020), Available at (https://blogs.vmware.com/cloudhealth/effective-cloud-center-excellence/) Accessed: March 2022

Weeks, D. E. (2017). "All Day DevOps: Modern Infrastructure Automation", DevOps.com (2 August 2017). Available at: https://devops.com/modern-infrastructure-automation Accessed: March 2022.

Wesley Chai and Stephen J.Bigelow (2017) "Cloud Computing". Available at https://www.techtarget.com/searchcloudcomputing/definition/cloud-computing Accessed: March 2022