

Devika Ravi

# Conceptual Framework for Evaluating and Selecting PaaS Solution for Airline Company

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<p>Platform as a Service (PaaS) is gaining popularity due to easier provisioning of developer's tools, improving productivity and bringing innovation in application development. The case company airlines want to adopt PaaS, and it is challenging for them to find an appropriate provider for their requirements.</p> <p>The purpose of this study was to develop a conceptual framework with set of criteria's to evaluate and select right PaaS solution for the airlines. The framework will be used by the e-commerce and customer experience (Cx) division of the airlines case company to choose right the PaaS solution.</p> <p>The qualitative research method was used in this study. The research design consists of five phases. In the initial phase the objectives of the thesis was defined, followed by the research design, current state analysis, a literature study, building of a PaaS Selection framework and finally findings on the proposed framework evaluation and conclusion.</p> <p>Data collection for this thesis was performed through various interviews and a questionnaire during different phases of the study. For a literature study, many existing research materials were collected and reviewed from various journal databases and major PaaS providers' criteria were summarized.</p> <p>After a thorough analysis of literature and experts interviews, the evaluation framework named as "Target Guiding Model" was built. The framework has two step guiding factors. The first guiding step defines how airlines as an organization should prepare to select and use a PaaS system. The second guiding level is a set of classifications and respective criteria grouped under each of the classifications. The proposed framework criteria are able to support the airlines in evaluating and choosing the right PaaS solution.</p>	
Keywords	Cloud Computing, PaaS, Airlines, Evaluation Framework

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## List of Abbreviations/Acronyms

AD	Active Directory
AMI	Amazon Machine Image
ARM	Azure Resource Manager
AWS	Amazon Web Services
CDN	Content delivery network
CLI	Command line interface
CPU	Central processing unit
CX	customer experience
EBS	Elastic Block Store
EC2	Elastic Compute Cloud
GAE	Google App Engine
GUI	Graphical User Interface
IaaS	Information as a Service
IAM	Identify and Access Management
IATA	International Air Transport Association
IoT	Internet of Things
IP	Internet protocol
IT	Information and Technology
KPI	Key Performance Indicator
NIST	National Institute of Standards and Technology
OTP	On-time performance
OS	Operating System
PCI DSS	Payment Card Industry Data Security Standard
PaaS	Platform as a Service
RDS	Relational Database Server
SNS	Simple Notification Service
S3	Simple Storage Service
SSL/TLS	Secure Sockets Layer/Transport Layer Security
SLA	Service Level Agreements
SES	Simple Email Service
SQS	Simple Queue Service
SITA	Société Internationale de Télécommunications Aéronautiques
SaaS	Software as a Service
SSD	Solid-state drive
TCO	total cost of ownership
VM	Virtual Machine
VPC	Virtual Private Cloud

## 1 Introduction

In recent years, the growth of cloud computing and cloud-based solutions has been phenomenal. Moving to the cloud has become the new normal. As we progress, most companies will engage in at least one cloud services. According to recent Gartner studies aggregate amount of cloud shift are estimated to increase \$216 billion in 2020 from \$111 billion in 2016.(Gartner, 2016)

Cloud models and solutions have simplified the traditional ways of, building and running software applications. Organizations are moving towards these cloud solutions to leverage their simplified approach. Platform as a Service (PaaS), a cloud model offers the developers a set of tools through cloud vendors, which allows the developers to concentrate on developing their software applications instead of setting and managing required infrastructure resources. PaaS eliminates the complex process of evaluating, buying, configuring and managing hardware resources and allows developers concentrate on building software applications. PaaS is an ideal solution if the organization wants to simplify the software license management, maintenance, and deployment process.

### 1.1 Background and Goals

Presently, cloud platform solution providers are offering different operating systems, databases, and web-servers, different architectural frameworks, similar services with different sets of features and performance levels at a competitive price. With so many complex moving parts, it is challenging and important to know what this means to an organization and how to choose the right pick to maximize the benefits it can offer. The objective of the present study was to develop a conceptual framework to evaluate and select the right PaaS criteria for the e-commerce and customer experience (Cx) division of an airline company.

For this thesis, 2 airline experts (1 Solution architect and 1 Technical architect), with a wide range of airline project experience around e-commerce and Cx division provided the all necessary data in the form of interviews, workshops, surveys, and questionnaires. The overall PaaS criteria selection framework was derived specifically for the airline industry and mainly for e-commerce and Cx division. The experts evaluated the outcome or the proposed final framework for airline industry in general and provided the necessary feedback. The case company related materials and information are confidential. The needed information was produced in a generic manner adhering to the company's security policies.

The main focus of the thesis was to find out the best criteria to be considered for airlines to choose the best PaaS solution available in the market.

Key objective of the thesis:

- To build a framework and set of criteria, enabling airline organizations to select the right PaaS solution.

The output of the study is a framework including criteria that could be applied to select the best PaaS solution. The study will also assist airline to focus on faster time to market, better application management, reduced complexity and increased agility.

## 1.2 Scope and Focus

The scope of the research was limited to PaaS service alone, not any other services such as Software as a Service (SaaS), IaaS (Information as a Service), etc. The focus of this research was also limited to e-Commerce and Customer experience divisions of the airline company. To achieve the goals of this thesis, qualitative research method is followed. Detailed study approach is presented in Chapter 2.

## 1.3 Structure

The contents of the thesis are structured in the form of chapters: In the first chapter, the goals of the research are introduced; why and what are the issues that are going



to be clarified, what exactly this study addresses and what are the results? The reader is presented with the business problem and why is it important to investigate the problem.

The Chapter 2 concentrates on how actually the study was conducted, introducing the research method, research plan, and data collection plan.

In Chapter 3, the reader is presented with a snapshot of the current state of the case company. This highlights the business problem and reasons for new requirements. Further this chapter presents cloud computing definitions, PaaS advantages and major PaaS provider with their features. The existing conceptual framework of Chapter 4 presents what other studies say about PaaS, its advantages and in the final section, previous research models on selection criteria's of cloud computing are evaluated. This chapter gives the reader an overview of the theoretical construct.

After the presentation of the theoretical work, Chapter 5 concentrates on analysing the data collected and focuses on building the framework.

Chapter 6 discusses the feedback from the case company. Improvements and suggestions were gathered as feedback.

The conclusion chapter also discusses the validity and reliability of the present study.

## 2 Research Approach, Design and Materials

The description of “How” the research was conducted and “what” are the data details collected and analysed are discussed in this section.

### 2.1 Research Approach

To solve the research problem and achieve the goal, this study uses a qualitative research approach. “A qualitative approach is more concerned with data that cannot be measured, such as people’s opinions, descriptions or observations”. (Walliman, 2013). “If a concept or phenomenon needs to be explored and understood because little research has been done on it, then it merits a qualitative approach. This type of approach may be needed because the topic is new, the subject has never been addressed with a certain sample or group of people, and existing theories do not apply with the particular sample or group under study” (Creswell, 2014 and Morse, 1991). This research method supports the thesis as the PaaS model of cloud computing is less explored and there exists minimal frameworks to choose PaaS model as a solution.

Also this thesis follows *case study* as a research design which is an inquiry within qualitative approach. “Case studies are a design of inquiry found in many fields, especially evaluation, in which the researcher develops an in-depth analysis of a case, often a program, event, activity, process, or one or more individuals. Cases are bounded by time and activity, and researchers collect detailed information using a variety of data collection procedures over a sustained period of time” (Stake, 1995; Yin, 2009, Creswell 2012). In this thesis in-depth analysis of a case corresponds to finding the right PaaS criteria for the airline company which will be chosen after analysing the extensive collection of data.

According to Yin, the research design is the logical sequence that connects the empirical data to a study’s initial research questions and, ultimately to its conclusion. The next step in this thesis was to design case study, which streamlines the research.

## 2.2 Research Design

In this section, the research design involved in this thesis is explored in detail. This research design consists of five phases: business problem, existing challenges, studying existing framework (data collection and analysis), building conceptual framework and evaluation of framework. Figure 1 represents the blueprint of the present study.

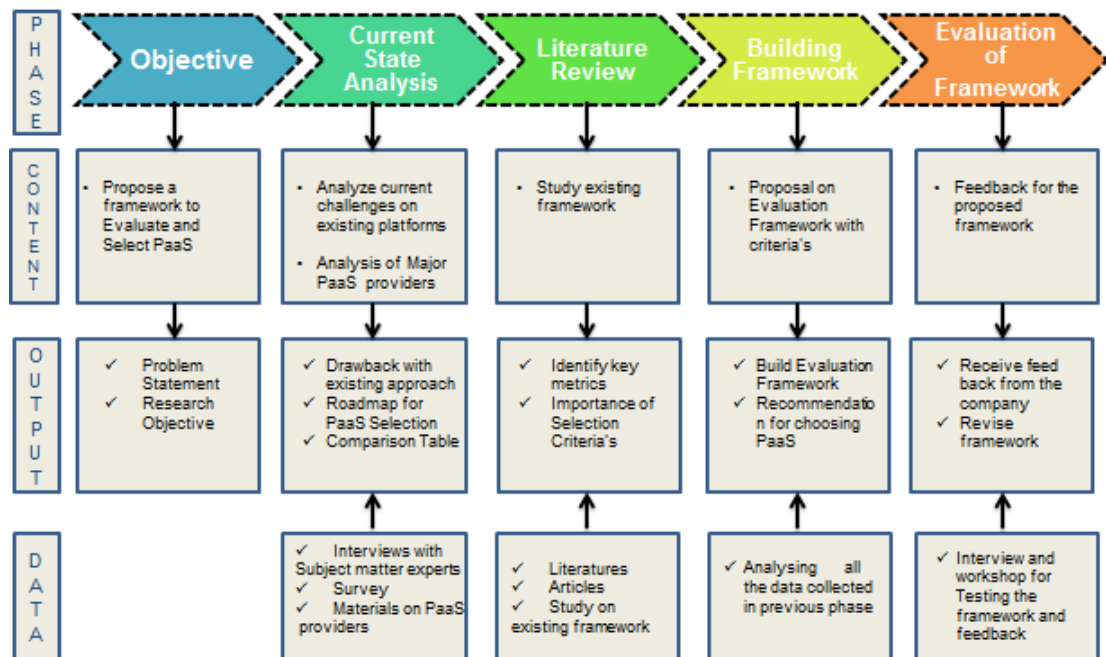


Figure 1: Blueprint of this research

According to Yin, "Every type of empirical research has an implicit, if not explicit, research design" (Yin, 1994). Above figure (figure 1) suggests the research design used in this thesis, in the first phase business problem is identified; objective, goals and outcomes are defined. The next phase is to analyze the technical architecture used by airlines. Purpose of this is to understand the current challenges and limitations faced by airlines with their existing platform. Also cloud computing fundamentals and models are introduced in brief and major PaaS providers' product and their features are also studied. In the third phase a literature review was done. In the design and developmental phase a conceptual framework to select PaaS was developed. Further this recommendation was be submitted to the case company for their feedback.

### 2.3 Data Plan

The types of data collection for this case study research are presented here. Data was collected in accordance with the case study research data collection techniques such as documents, interviews, questionnaires, scientific journals, articles, literatures, web forums, blogs, and existing research papers.

#### i) Interview Data

According to O'Hara et al., conducting interview is the most common method of data collection in qualitative research (O'Hara et al., 2011). The initial set of data was collected by scrutinizing existing architecture of the airline company to gain knowledge on how the current model is operating. It will be collected through series of semi-formal interviews. The data collected through interviews will determine the requirements and expectations of the new cloud model. Table 1 displays an overview of the experts' interview.

<b>Type of Interview</b>	<b>Position in the case company</b>	<b>Interview Date</b>	<b>Duration of the interview</b>
Questionnaire	Technical Architect	10-01-2017	2 hours
Questionnaire	Solution Architect	10-01-2017	2 hours
Feedback Workshop	Solution Architect and Technical Architect	24-04-2017	3hours

Table 1: Interview with subject matter experts - an overview

Table 1 tabulates the particulars of the interview such as date and time interviews were conducted. Interviews were conducted in different ways: one-on-one interview, through questionnaire and via messenger chats.

ii) Document Data

Yin states "Because of their overall value, documents play an explicit role in any data collection in doing case study research" (Yin, 2014). For collecting document data, lot of systematic search was made and a great deal of criticism was practiced as lots of materials were from internet, web blogs and forums. Documents were collected from National Institute of Standards and Technology (NIST), PaaS provider's own product publications, Literatures of previous solutions for choosing cloud services, articles and scientific journals.

iii) Workshop data for feedback

Feedback for the evaluation framework will be through interview. The interview was conducted with Technical architect and Solution architect. Their feedback is summarized in the Feedback chapter.

## 2.4 Next Research Steps

"Data collection is series of interrelated activities aimed at gathering good information to support validation and reliability" (Creswell, 2007). Evaluating and analysis of raw data is critical part of case study. Yin suggests for an analytical strategy, "Analysis depends on researcher's own style of rigorous empirical thinking, along with the sufficient presentation of evidence" (Yin, 2014). Adapting Yin suggestion researcher examines data, applies great deal of attention to detail in evaluating and analysing evidence without ignoring possible alternative interpretations.

### 3 Cloud Computing and PaaS Fundamentals

This chapter concentrates on data collection, which could be considered as case study evidence. This set of data is about exploring documentation of cloud computing, its characteristics and major PaaS providers and their features. First PaaS provider products are described in detail and finally, product comparison is also presented in tabular form.

#### 3.1 Cloud Computing

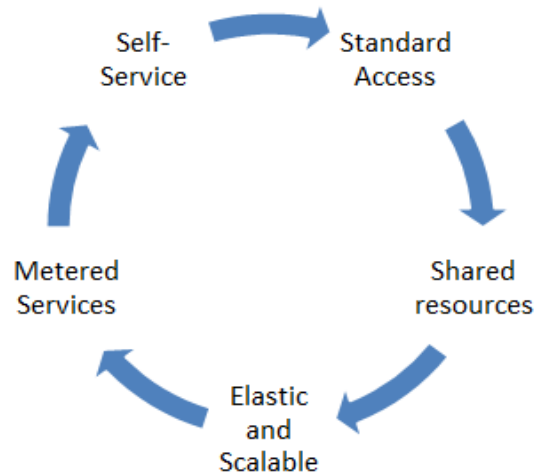
Cloud computing despite its existence and many embracing this technology in their everyday life in the form of e-mails, shared and stored data, still suffers from confusion, whether to adopt it or not. However, cloud computing is a broad topic which, is affecting all aspects of Information Technology (IT). Cloud is gaining popularity as enablers of digital business and the Internet of Things (IOT). Cloud adoption needs to be done through a planned research. The first step is to understand basic concepts of cloud computing.

Measurements standards and innovation laboratory, National Institute of Standards and Technology(NIST) defines cloud computing as : "Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction." (Mell and Grace, 2011).

By the above definition, we can infer that cloud computing is a model which allows users to access a shared pool of computing resources (servers, storage, networking, applications and services) easily, on-demand from anywhere, anytime using the internet. Also, the resources can be rapidly and easily provisioned and released with minimal efforts and without any service provider interaction.

### 3.1.1 Key Characteristics of Cloud computing service

The five essential characteristics of cloud computing service (NIST, 2011) with pictorial representation and explanation can be seen in Figure2.



*Figure2: Essential characteristics of cloud computing overview*

**On-demand self-service:** Allows users to quickly and automatically get access to the IT resources that they want without requiring any additional human interaction.

**Broad network access:** This gives the ability to access a service from any standard device connected to a network including PCs, laptops, mobiles or tablets.

**Resource pooling:** Compute, networking, and storage resources are pooled and shared across multiple users using multi-tenancy from different data centre locations, and also from reassigned datacentres according to users/consumers specifications. Customers do not necessarily know the exact sources of the resources provided.

**Rapid elasticity:** The computing resources are allowed to quickly expand or shrink according to the end users requirements. It also means that service providers are capable of pooling resources to meet any increasing or decreasing demand by aggregating those resources and releasing them as and when they are needed or not.

Measured services: Cloud infrastructure has the capability to monitor and measure the resources utilized. In this way, it provides transparency to both, end users and service providers.(NIST, 2011)

### 3.1.2 Deployment Model

Deployment model is the way in which company or organization access cloud computing, four types deployment model are defined as below:

**Public:** It is the most common model as it can be used by the general public with the registration of an account. It can also be used by companies and educational organizations. The location of the cloud is typically at the service provider's premises.

**Private:** This model is an inverse of the public cloud model. The resources of this model can be used by internal members of the particular organization exclusively. It can be developed by the same organization or a third party. It can exist in the same location as the organization or in some other location.

**Community:** It is an intersection between public and private models. It is for the exclusive use of a community who share a common concern. It may exist on the same or different locations.

**Hybrid:** The situation where there is a need for internal and external access of resources, a hybrid model can be used. This model can be a combination of all or any of the above models. Hybrid cloud model can vary from a simple to most complex ones.

### 3.1.3 Service Models

According to NIST service models are classified as below:

**Software as a Service (SaaS):**

End to end software package is provided as a service model. It provides customers, ability to consume application provider's service as it is with some or no modification. For example, Gmail is offered by Google and we are the consumers. Gmail can be ac-



cessed by a web browser or as an application through mobile devices. In this case, we as a customer do not have to worry about software updates or any maintenance of the Gmail. As a customer, we can only make some small changes, such as Gmail theme change. But we cannot have control over the hardware.

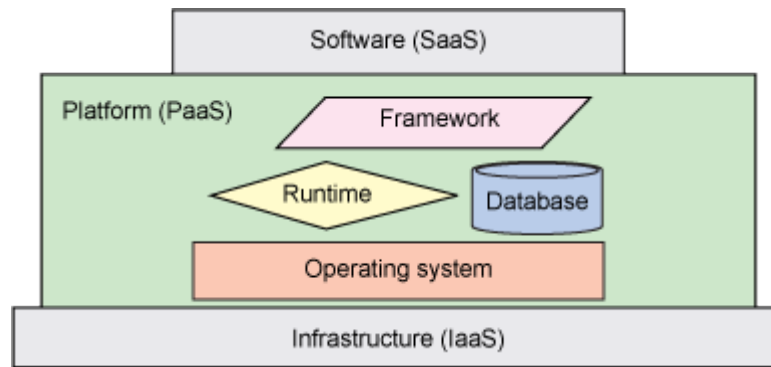
#### Infrastructure as a Service (IaaS):

It provides virtualized computing power, networks, storage and other services to consumers, using which consumers can deploy and run their own choice of software's and operating systems. However, customers do not have any control over physical layer (hardware resources such as servers, storage and network components) and abstract layer (software deployed across physical layer). Customers can manage their operating systems, storage, and deployed applications and also can have restricted control over the select of networking components like host firewalls.

#### Platform as a Service (PaaS)

This particular service is of great interest with respect to this thesis and it is important to understand the concept thoroughly. In this service, customers can deploy or create their own applications using service providers programming languages, libraries, services, and tools. Customers cannot control or manage physical layer (hardware resources such as servers, storage, and network components) and abstract layer (software deployed across physical layer), but has control over the configuration options of the hosting environment and deployed applications.

PaaS can be seen as service which, offers computing platform and solution's stack. We can further elaborate the two main components: Computing platform is the place where software's can be executed steadily if the code meets the standards of that platform. Figure 3 provides an illustration which helps to understand the relationship between classifications of cloud computing and the elements of PaaS (Orlando, 2011).



*Figure 3: A graphical interpretation of the relationship between classifications of cloud computing and the elements of PaaS (Orlando, 2011)*

Solutions stack consists of operating systems, runtime environments and any other middle ware that are required to develop and deploy the application. The solution stack sets difference among PaaS providers. Hence solution stack must be explored before choosing PaaS provider.

### 3.2 PaaS vs Traditional IT Development Model

When considering organizations using Traditional IT developmental model, it requires different types of the process setting such as acquiring web servers, database servers, installing operating systems, runtime and other middleware environments, frameworks or libraries for coding, in order to develop, run and test solutions. So setting up of the environment and making it work is a painful and time consuming process. For the business such as an airline the time to market is very important. The airline company is moving towards digitalization and considering PaaS, allowing business to leverage cloud computing capabilities for maximum returns.

PaaS is a game changer, which eliminates the Traditional IT ways and offers a modern cloud platform. PaaS platform comprises of all the elements part of Traditional IT model and also provides a global standard framework. Allows developers to design or implement large-scale solutions in an easy and efficient manner. Acquiring large scale infrastructure or platform provisioning is a matter of few clicks. Figure 4 shows an overview of the traditional and PaaS software development approaches.

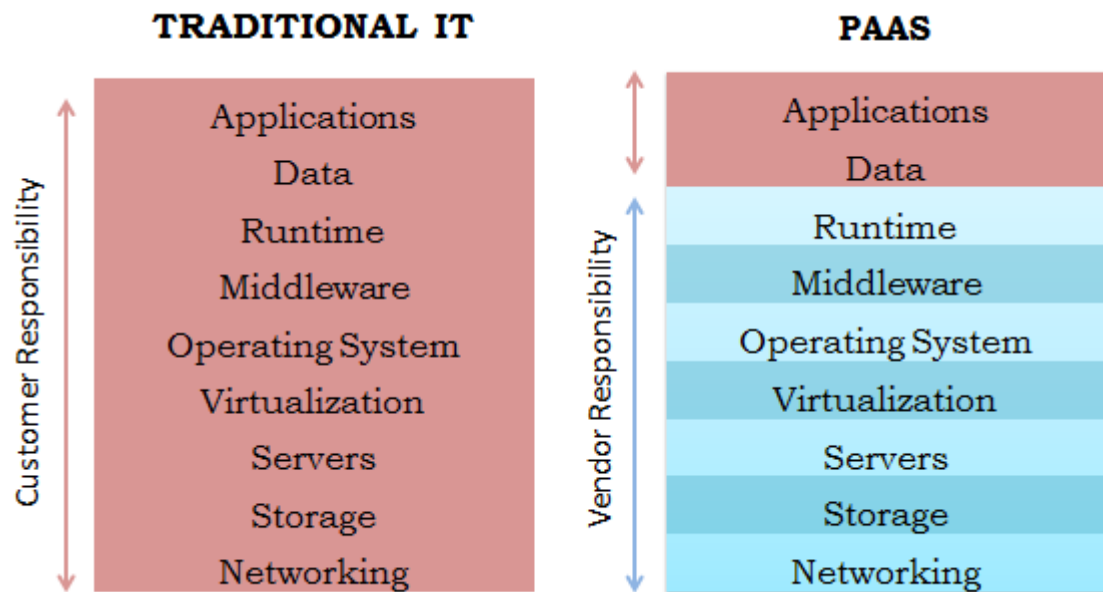


Figure 4: Overview of Traditional Software development and Cloud Computing Approach.

Above (Figure 4) clearly shows the comparison of responsibilities that the owner and vendors will have with respect to the traditional on-premise model and PaaS solution.

Choosing PaaS solution for the airline has to be done after a careful review of PaaS providers and its features. It is very important to understand the architecture of the airline company and choose the PaaS features according to requirements. If in any case a wrong selection is made then it would result in a failure and mean loss to the company.

### 3.3 Major PaaS Providers

Before exploring PaaS providers and their features it is essential to understand PaaS advantages and what exactly it should offer to customers. For organizations addressing business growth is their strategic goal. Business has become more dynamic, technology driven and disruptive. For example, Uber does not own taxi but are able to change the travel industry and Airbnb do not own a hotel, but changed the hospitality industry forever. Innovation and agility are inseparable. Organizations cannot succeed hyper-competitiveness using traditional methods of software development and deployment process. They are looking towards robust PaaS.

PaaS could be mentioned as a developer's tool since they can benefit from a variety of programming languages and frameworks that are available in the same platform. There are considerable reductions in complexity and cost, as PaaS architecture provides consistency and common platform for deployment of applications. PaaS deployment is simple, fast and easy and can be deployed with limited technical knowledge. PaaS developers get access to test environment, which mirrors development environment, which in turn lessens rollout problems. Recent research shows that companies not using PaaS are spending 80% on maintenance of the software and only 20% in building software. PaaS way of development encourages to innovate as developers can experiment. Also, PaaS developers get access to new and popular functionalities of application and data services.

PaaS development has collaborating features which have the benefit of stakeholders reviewing developers in the real-time. This real-time collaborating feature helps in building applications fast and further supports business agility. This is proof for ubiquitous access.

Another important aspect of business is downtime due to addition of application or hardware resources; this slows the uptime of the system. PaaS lessens down scaling time and ensures optimal availability of the newly scaled instances to the user. Upgrades and maintenance of software need no attention from the developer. Cost is also predictable as consumers can control their utilization.

The above mentioned PaaS benefits support essential cloud characteristics.

PaaS vendors in line with the above mentioned basic characteristics along with their own features were thoroughly studied and selected for the framework review.

### 3.4 Amazon

Amazon Web Services (AWS) offers a broad range of cloud-based products which offer on-demand computing platform.

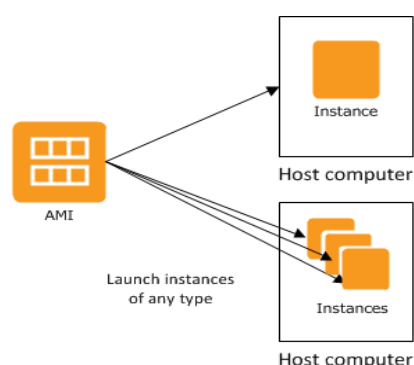
#### **Amazon EC2**

Amazon Elastic Compute Cloud commonly referred as Amazon EC2 are virtual machines that are launched in AWS cloud and they are created on demand or when combined with more advanced AWS services in response to conditions customers define .EC2 uses the pay as you go pricing model, customers pay only for the time resources are running. The customer can access resources across the globe, its means that customers can choose the locations that they can deploy their application. ( Amazon Web Services, 2017)

### **Main Components of Amazon EC2**

Amazon EC2 contains important services and components such as Amazon Machine Image(AMI) and instances. AMI is a preconfigured package required to launch instances. AMI contains software package bits for example an operating system, an application server and applications. Instances are copies of the AMI running as virtual servers in the cloud. Amazon has different AMI's with different software configurations for public. AMI's can be created and customized by customers according to their specifications. (Amazon Web Services, 2017)

An instance type is various configurations of memory, storage, networking capacity and Central processing unit (CPU) of the customer's instance. Different instance offers different hardware capacities. Customers can launch multiple instances of an AMI, as shown in the following Figure 5. (Amazon Web Services, 2017).



*Figure 5: Multiple instances launch from an AMI, (Amazon Web Services docs (e), Amazon EC2 Basic Infrastructure for Windows,2017)*

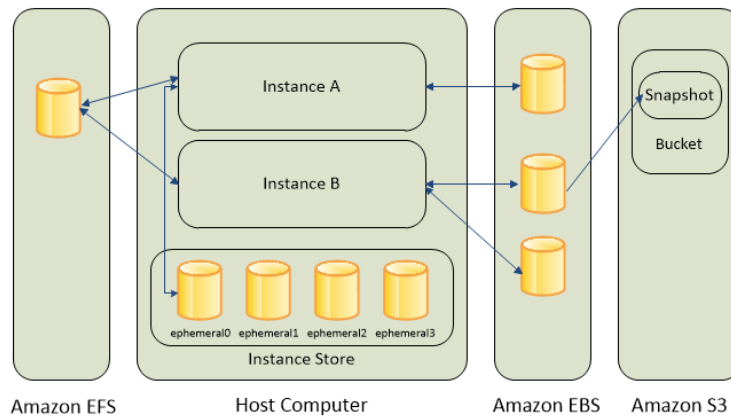
The customer can select an instance type based on their software or applications computing and memory requirements.

## **Regions and Availability Zones**

Amazon has servers and data centres around the world, for example North America, South America, Europe and Asia. Locations are further classified as regions and availability zones. And each region is separate geographical area with multiple locations termed as availability zones. Accordingly, Amazon EC2 instances can be launched in different regions and multiple locations, closer to customer to meet their requirements or to address legal issues if raised. Each availability zone is designed to be free from failures of the other availability zones. (Amazon Web Services, 2017)

## **Storage**

For customers who want to store data, Amazon EC2 offers three storage options: Amazon Elastic Block Store(Amazon EBS), Amazon EC2 Instance Store and Amazon Simple Storage Service(Amazon S3). Figure 6 shows the relationship between these types of storage. (Amazon Web Services, 2017)



*Figure 6: Relationship between Amazon storage options (Amazon Web Services docs (e), Amazon EC2 Basic Infrastructure for Windows, 2017)*

Amazon EBS is usually the most preferred storage because it provides hard disks that can be attached to running instance. Multiple volumes can be attached to instance. Customer can use EBS to create copy of back up data by creating snapshot of an EBS volume and save it in Amazon S3. Instance store offers to store all types of instances except micro instances. Data stored is of not much importance nor persistent. It offers

temporary storage in the sense data is deleted when the associated instance is terminated or stopped. Amazon S3 offers internet storage to customers. It allows data to be stored and retrieved from the web via simple web service interface. (Amazon Web Services, 2017)

### **Database:**

Amazon offers database solutions: Amazon Relational Database Server (Amazon RDS) is a relational database in the cloud which are easier to set up, operate and scale. Amazon DynamoDB is a non-relational; NoSQL a SQL database which are used to create a database table that can store and retrieve any amount of data. (Amazon Web Services, 2017)

### **Networking**

Amazon Virtual Private Cloud (VPC) supports wide array of networking features, it lets customer provision a section of AWS cloud, where customer can launch AWS resources in virtual network that customer define. Customer has complete control over their virtual networking environment, including selection of their own Internet protocol (IP) address range, creation of subnets, configuration of routing tables, and network gateways. Customers can use both IPv4 and IPv6 in their VPC for secure and easy access to resources and applications. Also customers can easily customize the network configuration for their Amazon Virtual Private cloud. They can also make use of multiple layers of security, including security groups and network access control lists, to help control access to Amazon EC2 instances in each subnet. (Amazon Web Services, 2017)

### **Elastic Load Balancing**

Amazon offers Elastic Load Balance, which distributes incoming application traffic across multiple targets (EC2 instances). It also monitors health of registered targets and directs incoming traffic to healthy targets. This feature increases fault tolerance of the customer applications. (Amazon Web Services, 2017)

### **Content Distribution**

Amazon CloudFront is a content delivery network (CDN) that accelerates delivery of websites, API's, videos and other web products. Integrates with other AWS products providing maximum benefits to developers. (Amazon Web Services, 2017)

### **AWS Elastic Beanstalk**

Amazon Beanstalk is a service offered by Amazon, which allows developers to quickly provision and manage applications in AWS cloud. Developers can upload the developed application and Beanstalk automatically handles deployment from capacity provisioning, load balancing and application monitoring. Beanstalk supports deploying and scaling of web applications and services developed with Java,.NET, PHP, Python, Node.js, Ruby, Go, and Docker with servers such as Apache, Microsoft IIS, Apache HTTP server, Passenger. ( Amazon Web Services, 2017)

AWS Toolkit for Visual Studio and Eclipse allows deployment and management of user's application to AWS Elastic Beanstalk without leaving IDE. When the application is running Beanstalk automatically manages version deployment, monitoring, health check and gives basic log file access. However if developer wants to manage some of the infrastructure they can do so with Elastic Beanstalk's management capabilities. (Amazon Web Services, 2017)

With Beanstalk customer can choose operating system (e.g., Amazon Linux or Windows server 2012 R2) , select database options from EC2 database, direct log in access for immediate troubleshooting ,run applications in various availability zones, to enable HTTP protocol on the load balancer for improved security, to get notifications on application events and health through Amazon CloudWatch, to modify application server setting and environment variables, run other application components side-by-side in Amazon EC2 and to access log files without logging into servers. ( Amazon Web Services, 2017)

### **Auto Scaling**

Auto scaling feature ensures the customer's application availability by having the correct number of instances handle the load of application. Amazon EC2 can be scaled up and down according user defined configurations. Auto Scaling can increase and de-



crease as per demand to maintain performance and save cost. According to Amazon auto scaling is beneficial for both types applications usage i.e., applications usage varying weekly, daily or even hourly and stable demand pattern. Auto scaling can be scaled dynamically by Amazon CloudWatch metrics or any other schedule customer defines. Customers can receive notification regarding auto scaling actions or when it completes action via Amazon Simple Notification Service (Amazon SNS) along with Amazon CloudWatch. (Amazon Web Services, 2017)

### **Messaging**

Amazon offers four messaging options: Amazon Simple Queue Service(SQS) is totally managed message queues for communicating between applications and micro services. Amazon Simple Notification Service (SNS) lets customer send message individually or to large number of recipients. For example: push notification and email recipients. Amazon Pinpoint is push notification for mobile apps. Amazon Simple Email Service (Amazon SES) is email service built for Amazon's customer base. (Amazon Web Services, 2017).

### **Search**

Amazon CloudSearch is a simple cost effective managed search solution for the customer's mobile application or web sites. (Amazon Web Services, 2017)

### **Distributed Computing**

Amazon Elastic Map Reduce is a managed big data framework which process vast amount of data in easy, fast and cost-effective manner across scalable Amazon EC2 instances. Amazon Simple Work Flow Service (SWF) helps build workflows and run them on cloud environment. Tasks can be performed either sequentially or parallel. (Amazon Web Services, 2017)

### **Web Interface**

AWS Management Console lets user access AWS account in all aspects, monitor usage, manage security aspects and create IAM users. (Amazon Web Services, 2017)

## **Identity and Access**

Amazon EC2 has AWS Identify and Access Management (IAM) feature integrated. These features allows customer to create users and groups under AWS account, assigns security credentials to each account. Using IAM with EC2 users in the organization can control specific AWS resource usage and tasks performed using Amazon EC2 API. (Amazon Web Services, 2017)

## **AWS CloudFormation**

Creation of AWS resources, managing version control and keeping track of AWS resources can be done by AWS CloudFormation. This can be done by using templates available or customers can create their own template to describe the AWS resources, runtime resources required to run the application and any other dependencies. AWS CloudFormation takes care of deploying the order of services and dependencies. Once deployed customers can edit and update in the same manner as version controls are done with software development process. AWS Management console, AWS command line and API's can be used to deploy, update resources. CloudFormation is free of charge and comes as an add-on with AWS resources need to run the application. ( Amazon Web Services, 2017)

## **Pricing**

AWS is advantageous with no charge for AWS Elastic Beanstalk. However customer has to pay for AWS resources (e.g. EC2 instances or S3 buckets) that customers create to store and run the application. Customers pay for what they use and there are no minimum fees and upfront costs. Free tier offers for AWS resources as new user for twelve months are:

- 750 hours per month of Windows, Linux, RHEL, or SLES t2.micro instance usage
- 750 Hours per month shared between Classic and Application load balancers, 30 GB of Amazon EBS, 5 GB of Standard Storage S3

- For Amazon RDS 750 Hours per month of database usage 20 GB of DB Storage: any combination of General Purpose (SSD) or Magnetic 20 GB for Backups with 10,000,000 I/Os. ( Amazon Web Services, 2017)

After the free tier period ends estimate of monthly bill for Elastic Load Balancing of 15 GB/month is \$0.09 with Europe central as the location.  
<http://calculator.s3.amazonaws.com/index.html#key=calc-BeanstalkDefault-140324>

(Amazon Web Services, 2017)

### **High Availability and Vendor Lock in**

AWS will put efforts to make Amazon EC2 and Amazon EBS each available with a Monthly Uptime Percentage of at least 99.95%, in each case during any monthly billing cycle (the "Service Commitment"). This also assures for Beanstalk which works with AWS EC2. In the event Amazon EC2 or Amazon EBS does not meet the Service Commitment, customer will be eligible to receive a Service Credit. (Amazon Web Services, 2017)

Beanstalk is part of AWS Infrastructure and AWS platform provides wide range of tools to migrate applications to Beanstalk. Migration of application to beanstalk is easy rapid. However, Vendor lock-in concern exists in AWS for applications built and deployed with in AWS. With many tools and features available to migrate and code portability this concern can be addressed easily. (Amazon Web Services, 2017)

### **Security**

AWS Certificate Manager (ACM) is a service that lets customer easily provision, manage, and deploy Secure Sockets Layer/Transport Layer Security (SSL/TLS) certificates for use with AWS services. Customers can use SSL/TLS certificates provisioned from AWS Certificate Manager with AWS Elastic Beanstalk environments by selecting a certificate from the Elastic Beanstalk console. This helps customer easily secure network communications between customers Elastic Beanstalk applications and end users. (Amazon Web Services, 2017)

Amazon also offers AWS Identity and Access Management (IAM) feature which is authentication configuration for AWS services. It can be used along with Beanstalk. (Amazon Web Services, 2017)

### 3.5 Microsoft Azure

Azure is a collection of integrated cloud services provided by Microsoft. Azure offers customers a wide range of self-managed tools, applications and frameworks as a service to build, deploy and manage applications through global network of data centers. Customers pay only for the compute resources that they have used and the billing is based on per minute usage. Azure offers enhanced security measures and encrypts sensitive data. (Microsoft, 2017)

Main Components:

Azure has lot of components that can be used together or separately to form PaaS solution. Some of the integrated components are: Compute, networking, Identity and Access, Media and CDN, Storage, Data and App. (Microsoft, 2017)

#### Compute: Virtual Machine

Azure Virtual Machine (VM) is on-demand scalable product, which offers control over the computing environment. Azure VM provides flexibility of virtualization for developing, testing and running applications, with wide range of tools and applications. Various ways or advantages of using azure's VM are:

VM provides developers an easy way to configure their computers through which they can code and test an application. This feature helps customers create, use and delete in an economical way. Optimal use of hardware resources by running in the cloud, Azure handles this efficiently by providing hardware resources when there are larger spikes in the demand and shutdowns when there is no demand. Extending customer's own data centre into the public cloud, on using Azure Virtual Network user's organization can create virtual network (VNET) and add VM to VNET. This will make deployments easier and less expensive rather than running VM in the customer's own data centre. Azure VM's can be managed using command-line tools and a browser-based portal or directly through the REST API. (Microsoft, 2017)

#### Storage in VM

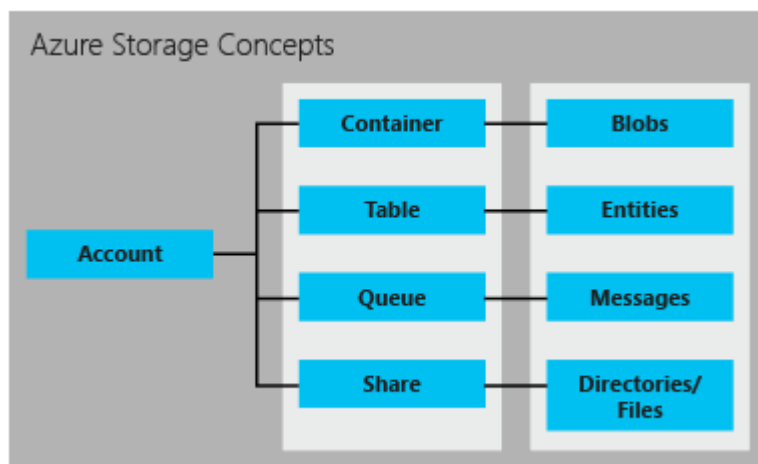
Azure VM has two disks: a Windows operating system disk and a temporary disk. Operating system disk is created from an image. Image and operating system disk are virtual hard disks (VHDs) that are stored in an Azure storage account. VM can also have one or more data disks stored VHDs. (Microsoft, 2017)

### Regions and availability

Azure operates around the world in multiple datacentres. Datacentres are grouped into geographic regions and region is called as location. Currently Azure services are offered in more than thirty regions, this gives customer the flexibility, availability, redundancy to develop applications. VM's can be created in defined geographical locations like North Europe, West US, and Southeast Asia. (Microsoft, 2017)

### Storage

As data grows it is hard to store and manage, which is a concern for developers and IT teams. This concern is addressed by Microsoft Azure Storage which offers massively scalable, highly available and secure storage for their data. Azure storage provides the following services: Blob storage, Table storage, Queue storage, and File storage. The following Figure 7 shows the relationship between Azure account and Azure storage resources. (Microsoft, 2017)



*Figure 7: Relationship between the Azure storage resources in a storage account (Microsoft, 2017).*

As seen in Figure 7, the way the storage resources are structured and organized in Azure is clear. Azure provides a very highly scalable solution for storage.

## Networking and Security

Azure allows organizations to create a virtual network (VNet) which can be added to Azure's VM. This approach extends organizations own data centre to be in the cloud. Customers can have full control over DNS settings, IP address blocks, route tables and security policies within the network. Also users can connect the virtual network to on premise network using virtual network gateways (connectivity options) provided by Azure. (Microsoft, 2017)

## Database

Azure provides following data bases: Azure SQL Database, SQL Data Warehouse, SQL Server Stretch Database, Document DB, Table Storage, Redis Cache, and Data Factory. (Microsoft, 2017)

Azure SQL Database is a cloud based relational data base for developers. With the use of SQL database building and maintaining applications have become more productive. Since SQL database is based on the SQL Server engine and it supports existing SQL Server tools, libraries, and APIs resulting beneficial for developers to build new solutions. SQL Database supports features relating to performance, scalability, elastic pools to maximize resource utilization (elastic pools are designed to handle unpredictable usage patterns) and manageability. (Microsoft, 2017)

Azure DocumentDB is a NoSQL service for relational database systems which eases development challenges. NoSQL embraces industry standards like JSON and JavaScript, offers predictable performance and grows to meet needs of the application. Document DB is schema-free NoSQL database providing read and write serves under few milliseconds. These efficient benefits make DocumentDB an excellent choice for applications that need global replication and seamless scale. (Microsoft, 2017)

Azure Redis Cache is based on the open-source Redis cache (open source in memory in-memory data structure store, used as a database, cache and message broker), which provides high throughput, consistent low-latency data access to scalable Azure applications. (Microsoft, 2017)

## Cloud Services

Cloud Services offered by Azure is an example of PaaS service, which works in conjunction with other Azure services like VM, Blob and VNet. Cloud Services are created to support applications that are scalable, reliable and low-cost to operate. Like any other Azure service Cloud Services are also hosted on VMs and customers can have more control over the VMs, also customers can install their own software on to Cloud Services. (Microsoft, 2017)

Cloud Services consists of two different VM options: Web role and Worker role. They can be thought of as templates for the servers that will be deployed, defining the OS version, the size of the machines, and the application type that will be run.

- Web role runs a version of Windows server with Internet Information Services (IIS).
- Worker role runs a version of Windows server without Internet Information Services (IIS).

There can be any combination of two different VM hosting in a cloud service. A simple application might use only one web role, while a complex application might use a web role handle incoming requests from users, then pass requests to create worker role for processing. (Microsoft,2017). Figure 8 shows different VMs of single application running in the same cloud service.

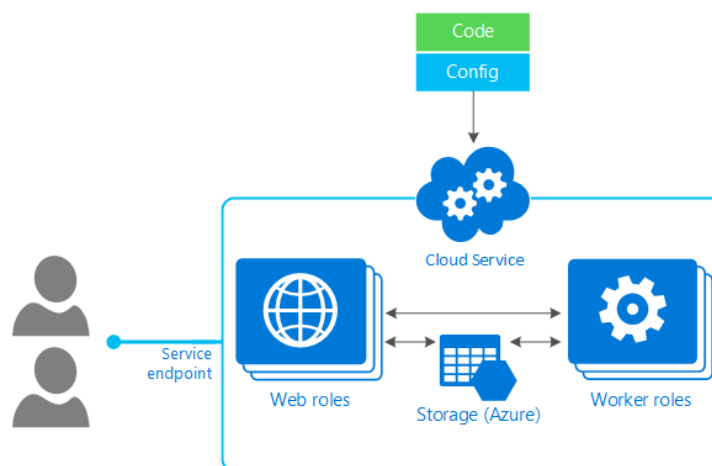


Figure 8: Different VMs of the single application are running in the same Cloud Services. (Microsoft, 2017)

In Figure 8 above, all VM's in a single application are running in the same Cloud Service hence users access the application through a single public IP address and the re-

quests are automatically load balanced across VM's. Azure platform will scale and install VM's in Cloud Services in order to avoid hardware failure. This proves that Cloud Services are PaaS, where customers just deploy the application and managing of applications are handled by Azure. (Microsoft, 2017)

#### Azure Autoscale

Autoscale is an integrated feature of Cloud Services, Mobile Services, Virtual Machines, and Websites which helps applications perform their best when the demand changes. Performance factors are different for different applications such as CPU-bound, memory bound. Autoscale can scale services according to custom settings the users define. With a scheduled autoscale feature, customers do not have to wait for traffic to take down their application or website. Scheduled autoscales are preconfigured to handle the load. Autoscale is also elastic and cost effective; it means the customer does not have to pay for the machine that they are not using. Autoscale can send alerts on any key performance metrics when users have set it. Users can also set triggers on when autoscale can start. (Microsoft, 2017)

#### Azure Load Balancer

Azure Load balancing feature delivers highly-available and scalable applications easily to users. Azure Load balancer supports four layer TCP/UDP based protocols such as HTTP, HTTPS and SMTP used for real time voice and video messaging, that distributes incoming traffic among healthy instances of services defined in a load-balanced set. Load balancer automatically scales as and when application traffic increases without user interference offering high availability and robust performance for the user's applications. Internal Load balancer is used to handle traffic between virtual machines in a virtual network, between virtual machines in cloud services, or between on-premises computers or can be used to create multi-tiered hybrid applications. (Microsoft, 2017)

#### Azure Content Delivery Network(CDN)

Azure CDN provides developers a consistent and global solution for delivering high-bandwidth content that is hosted in Azure or any other geographical location. CDN can be used as a cache for serving dynamic content, such as a PDF report or graph based on specified inputs; and also cache available objects loaded from Azure blob storage, a



web application, virtual machine, application folder, or other HTTP/HTTPS location. Benefits of using CDN are fast delivery, reduce load times, save bandwidth, low latency and increase responsiveness. (Microsoft, 2017)

### Messaging

Azure Notification Hubs offers multi-platform, tailor made, easy to use scaled push notification to any platform from any back end and instant broadcast push to millions of mobile devices with single API call. Notification hubs are used to send news about low latency to millions customers, notification of offers and discounts to location-based interested users, event related notifications and many more. (Microsoft, 2017)

### Search

Azure Search is a search-as-a-solution that provides customers ready to use service with which customer can populate their data and add them to their web or mobile applications, leaving server and infrastructure management to Microsoft. Azure Search gives users a powerful experience, extensive and multiple language support, auto completed search bars and geo-spatial support. (Microsoft, 2017)

### Distributed Computing

Azure Service Bus is a highly-reliable cloud messaging service between applications and services, even when one or more is offline. It is available in all Azure regions and eliminates the burdens of server management and licensing. (Microsoft, 2017)

### Azure Active Directory

Azure Active Directory(Azure AD) is Microsoft's multi-tenant broad identity and access management cloud solution that provides a powerful set of capabilities to manage users and their groups. Application developers can focus on their application building as Azure AD offers quick and easy integration to world class identity management used by many organizations across the globe. Azure AD provides secure cloud based solutions, efficient IT processes, cost effective and compliance adherence. (Microsoft, 2017)

### Azure Resource Manager

Azure Resource Manager (ARM) is a service that works with resources in the customer's solution as a group. It can be explained as follows: the infrastructure the customer's use is made up of many components such as virtual machine, virtual network, storage, database, web app or third party services, customers see them as interdependent parts and want them to be deployed, managed and monitored as a group. ARM enables working of resources as a group. (Microsoft, 2017)

#### High Availability and Vendor Lock-in

According to Microsoft, for Cloud Services, they guarantee that when customers deploy two or more role instances in different Update Domains, at least one role instance will have Role Instance Connectivity at least 99.95% of the time. The following Service Levels and Service Credits are applicable to the customer's use of Cloud Services:

If monthly uptime is < 99.95% then service credit is 10% and if monthly uptime is <99% then service credit is 25%

If the customer is using server instance with Azure VM or Cloud Service, they can get servers from a different vendor and configure them and they can also easily move the code to a different provider. This is clearly a low vendor lock in. However the problem is with Amazon DynamoDB and Azure Service Bus for which there are alternatives available. (Microsoft, 2017)

#### Pricing

Azure Cloud Services have pricing options for different configurations of instances and disk sizes. For general purpose such as websites, small to medium databases and everyday applications, with region as North Europe per hour Azure offers the following price as shown in Figure 9.

INSTANCE	CORES	RAM	DISK SIZES	PRICE
A0	1	1 GB	20 GB	€0.0169/hr
A1	1	2 GB	40 GB	€0.0675/hr
A2	2	4 GB	60 GB	€0.135/hr
A3	4	7 GB	120 GB	€0.2699/hr
A4	8	14 GB	240 GB	€0.5398/hr

Figure 9: Price of Basic Cloud Services(General Purpose)

For more memory intensive, large data base and high throughput resources Azure has different pricing options. (Microsoft,2017)

### Security

Azure does not offer built in SSL for Cloud Services. However, a third-party SSL can be configured. Azure Active Directory helps customer to manage identities, credentials and access control. Also offers multi-factor authentication for highly secure sign-in. Provides developers with industry-standard protocols—such as SAML 2.0, WS-Federation, and OpenID Connect, which will help them integrate identity management into their apps across different platforms, and to build mobile and web apps that integrate with Microsoft and third-party APIs with OAuth 2.0. Azure provides Virtual Network for Cloud Services along with Azure VM's. (Microsoft, 2017)

### 3.6 Google Cloud Platform

Google cloud platform offers a wide range of scalable computing services. From global load balanced, flexible services to resilient single-instance the VM's the customer can choose to suit their needs and they can do this by accessing resource across globe. By using managed application platform customer can gain lots of flexibility and fully utilize benefits of container technology. Google App engine lets developers' focus on code, freeing them from operational details of deployment and hardware management. It can be imagined as a spectrum where the resource management at one end is customers and the other end is Google's. (Google Cloud Platform, 2017). Figure10 shows the spectrum of resource management.

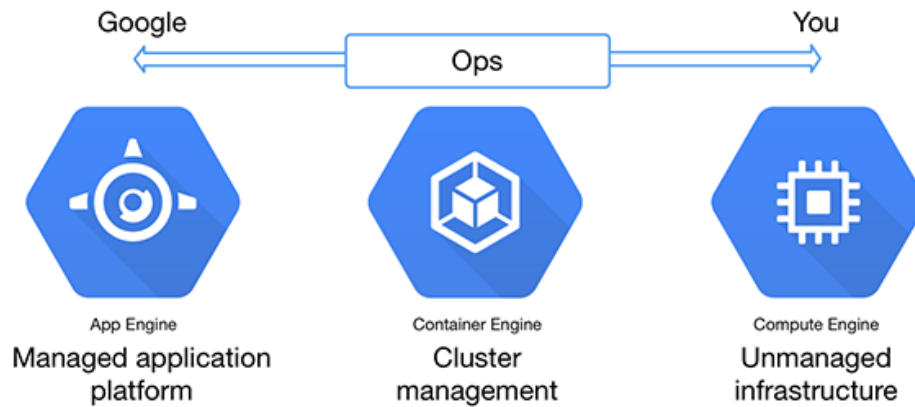


Figure 10: Spectrum of resource management (Google Cloud Platform, 2017)

In Google Cloud Platform software and hardware are services; these services provide access to resources. Google Cloud Platform has a projects concept. A project is an organizing entity for resources that the customer is building. A project is made up of the settings, permissions, and other metadata that describe the customer's applications and each project has a name (provided by customer), project ID(customer or Clod Platform can provide) and project number(provided by Cloud Platform). (Google Cloud Platform, 2017)

Cloud Platform provided three ways to interact with services and resources:

A web based graphical user interface through which customer can manage Cloud Platform projects and resources. (Google Cloud Platform, 2017).

Google Cloud SDK provides the *gcloud* command line tool if the customers prefer to work in terminal window. *gcloud* tool can be used to manage both developmental workflow and customer's Cloud Platform resources. (Google Cloud Platform, 2017)

Cloud SDK includes client libraries that enable customers to create and manage resources. Client libraries expose two API's: App API to provide access to services and Admin API's to provide functionality for resource management. (Google Cloud Platform, 2017)

Google offers smart pricing options, such as no upfront costs, pay as you go by paying for services on need basis, customers stop paying when they turn off the service. (Google Cloud Platform, 2017)

### Geography and Regions

Google offers customers different Regions and zones where they can deploy applications to meet their requirements on latency, availability and durability. Google provides its service from North America, Europe and Asia. Regions are independent geographic areas that consist of zones. A zone deployment area for cloud platform is within the same region. Each zone is identified by a name that combines a letter identifier with the name of the region. (Google Cloud Platform, 2017)

### Main Components

Google Compute Engine offers customers scalable, high performance, global load balanced virtual machines (VM's) to build their own infrastructure which will give them more control and flexibility. A different configuration of predefined virtual machine is offered by Google Compute Engine. Customers can create their own virtual machine to suit their needs; they can tailor Custom Machine types to save cost. Google Compute offers persistent disks and Local SSD. Persistent disk of network storage can be attached to VM's. If a VM is terminated persistent disk retains data and can be attached to other disk, also customer can take snapshot and create new disk from that snapshot. Local Solid-state drive(SSD) , block storage is also provided by Google Compute Engine, these SSD's are attached to server hosting the virtual machine instance offering very high input/output operations per second (IOPS). (Google Cloud Platform, 2017)

### Storage

Google Cloud storage offers unified object storage world-wide and retrieval of any amount of data at any time. Google cloud storage can be used for different storage purpose such as serving website content, storing data for archival and disaster recovery, or distributing large data objects to users via direct download. And they can be accessed as Nearline and Coldline. Nearline if the data is accessed frequently less than once a month. Coldline access if the data is accessed less than once a year.

(Google Cloud Platform, 2017)

### Network

Google Cloud Platform networking is global feature that spans over all the services. Google's Andromeda architecture allows creation of networking elements with software, this software based networking allows Cloud Platform's service to implement

networking feature that fit customer's needs, such as firewalls for virtual machines in Google Compute Engine, fast connections between database nodes in Cloud Bigtable, or fast query results in BigQuery. (Google Cloud Platform, 2017)

#### Google Cloud Load Balancing

Google Cloud Load balancers distribute incoming traffic across multiple regions or single, close to client and also to meet the high availability requirements. There are many varieties of Cloud Load Balancing integrated with Google Cloud CDN for optimal content delivery and application. Single Anycast IP of Cloud Load Balancing can put all front end instances to backend in regions around the world. It can automatically put all unhealthy fractions in the backend in case of multi-region failover. Cloud Load Balance can be applied to all the traffic such as HTTP(s), TCP/SSL, and UDP. (Google Cloud Platform, 2017)

#### AutoScaling

With autoscaling an application's increase during demand will be gracefully handled and reduces costs when the resources lower in demand. Customers have to define autoscaling policy (Average CPU utilization, Stackdriver Monitoring metrics and others) and the autoscaler performs automatic scaling based on the measured load. (Google Cloud Platform, 2017)

#### Database

Cloud SQL is a fully managed database service which is easy to setup, maintain, manage and administer customer's MySQL and PostgreSQL (beta) databases in the cloud. It also offers features such as: scalability, high performance, easily accessible from anywhere and any application, security, standard API's and protection. CloudDatastore is highly scalable NoSQL database for customer's application which automatically handles sharing and replication. (Google Cloud Platform, 2017)

#### App Engine

Google App Engine referred as GAE is PaaS service offered by Google Cloud Platform, which provides platform for developing and hosting web applications. Google scales applications automatically if there increase in customer's web traffic and if customer's software needs security update it is also handled by Google. (Google Cloud Platform, 2017)

Google provides two options to build the customer's app: Standard and Flexible environment.

Standard Environment is based on preconfigured containers, (instances running on Google's Infrastructure) with one of the several runtimes available. Available runtimes are Java 7, Python 2.7, Go and PHP and each of these runtime include libraries that support App Engine Standard API. App Engine Standard has features such as : automatic scaling and load balancing, persistent storage with queries, sorting and transaction, for performing work outside the scope of a request asynchronous task queues are created, scheduled tasks for triggering events at a particular time or regularly and integrates with other Google API's and cloud services.

The customer's application runs within their own secure environment independent of hardware, server location and operating system, allowing App Engine standard environment to distribute requests across multiple servers and scaling servers to meet traffic demand. (Google Cloud Platform, 2017)

Flexible Environment supports automatic scaling while balancing load and all other services Microservices, authorization, SQL and NoSQL databases, traffic splitting, logging, versioning, security scanning, and content delivery networks are all supported natively are also supported natively . Additionally the App Engine flexible environment allows customers to customize their runtime and even operating system using Docker files. Runtime supported are Java 8 / Servlet 3.1 / Jetty 9, Python 2.7 and Python 3.5, Node.js, Ruby, PHP, .NET core, and Go. Customers can use their own run time by providing a custom Docker image or Docker file from an open source. App Engine flexible environment also offers customization of infrastructure and performance. (Google Cloud Platform, 2017)

Software Development Kits (SDK) for App Engine are available in all supported languages. Each SDK includes: All of the APIs and libraries available to App Engine, A secure sandbox environment that replicates all of the App Engine services on local computer, deployment tool which allows the customer to upload their application to cloud and manages version control. (Google Cloud Platform, 2017)

Cloud Endpoints are used in the standard environment to generate APIs and client libraries which, customers can use to simplify data access from other applications. Endpoints make it easier to create a web backend for web clients and mobile clients, such as Android or iOS. (Google Cloud Platform, 2017)

#### Content Delivery Network (CDN) for Cloud Platform

Google Cloud CDN takes the most advantage of Google's globally distributed edge, points of presence to accelerate content delivery for websites and applications served out of Google Compute Engine and Google Cloud Storage. When the HTTP(s) Load balancing are set customers have to enable Cloud CDN with a single checkbox. Cloud CDN also lowers network latency and reduces serving costs. (Google Cloud Platform, 2017)

#### Messaging

Google Cloud Pub/Sub is a globally distributed, fully managed message bus which scales according to customer's need. It is real-time messaging service that allows customers to send and receive messages between independent applications. Cloud Pub/Sub offers Push and Pull delivery options through which customers can access the message from the Internet or behind a firewall. (Google Cloud Platform, 2017)

Google Cloud Dataproc (Apache Hadoop, Apache Spark, Apache Pig, and Apache Hive) service helps customer process, transform and understand vast quantities of data at low-cost. Costs could be reduced by quickly creating managed clusters of any size and turn them off when the customer has finished his task. Cloud Dataproc integrates across Google Cloud Platform products, which gives the customer a powerful and complete data processing platform. (Google Cloud Platform, 2017)

#### Google Cloud Identity and Access Management (IAM)

Google IAM is free add-on service comes along with other Cloud services. IAM authorizes the administrator to take action on particular resources, giving full control and visibility to manage cloud resources centrally. IAM offers right tools to manage resource permission without any hassles and with automation. Cloud IAM are designed in a simple way which lets customer manage access control across all Google Cloud Platform resources consistently. (Google Cloud Platform, 2017)



### Management Services

Stackdriver Monitoring offers visibility into the performance, uptime, and overall health of cloud-powered applications. Stackdriver Monitoring discovers and monitors customers cloud resources automatically, whether they are running on Google Cloud Platform or Amazon Web Services. The service includes default dashboards for many Cloud Platform and AWS services out of the box and incorporates not only metrics but also critical metadata from these providers, making it easy to understand the relationships between components and monitor autoscaling clusters. (Google Cloud Platform, 2017)

Google Cloud Deployment manager is an infrastructure management service which automates the creation and management of customer's Google Cloud Platform resources for you. Using Deployment Manager, you can create flexible templates that deploy a variety of Cloud Platform services, such as Google Cloud Storage, Google Compute Engine, and Google Cloud SQL. (Google Cloud Platform, 2017)

### High Availability

Google offers the following terms of service: "During the Term of the Google App Engine License Agreement, the Google App Engine and Google Cloud SQL License Agreement, Google Cloud Platform License Agreement, or Google Cloud Platform Reseller Agreement (as applicable, the "Agreement"), the Covered Service will provide a Monthly Uptime Percentage to Customer of at least 99.95% (the "Service Level Objective" or "SLO"). If Google does not meet the SLO, and if Customer meets its obligations under this SLA, Customer will be eligible to receive the Financial Credits" (Google Cloud Platform, 2017)

If Google is not meeting SLO, then it offers customer the following Financial Credit options:

<i>Monthly Uptime Percentage</i>	<i>Percentage of monthly bill for Covered Service which does not meet SLO that will be credited to future monthly bills of Customer</i>
99.00% – < 99.95%	10%
95.00% – < 99.00%	25%
< 95.00%	50%

(Google Cloud Platform, 2017)

### Vendor Lock-in

Google App Engine is easy and most scalable product which comes with vendor lock in issue. Product combinations like DataStore and App Engine platform code are services are not easy to migrate. (Google Cloud Platform, 2017)

### Pricing

Google App Engine applications run as instances in the standard or flexible environments. Instances within standard environment have access to a daily limit of resource usage that is provided for free, defined by a set of quotas (free quotas where every application gets an amount of each resource for free), beyond quota applications will incur charges. Applications running in the App Engine standard environment are deployed to instance classes that customers specify. For example Instance class B1 costs \$0.05 per hour per instance. Applications running in the App Engine flexible environment are deployed to virtual machine types that customers specify. Cost for flexible environment is as below: (Google Cloud Platform, 2017)

Resource	Unit	Unit cost
vCPU	per core hour	\$0.0526
Memory	per GB hour	\$0.0071
Persistent disk	per GB per month	\$0.0400 (Google Cloud Platform, 2017)

### Security

Google assures that all Cloud Platform are built with security as core design and development requirement. In addition Google's site reliability teams supervise operations of the platform for the high availability and prevent misuse of platform resources. Each and every service is managed through a secure global API gateway infrastructure and this serving infrastructure is only accessible over encrypted SSL/TLS channel. Every request requires login the inclusion of a time-limited authentication token generated via human login or private key based secrets through the authentication system which follows encrypted login.

Since access to all Google Cloud Platform is regulated authenticated infrastructure as other Google services, customers can use existing Google accounts or set up a regulated Google managed domain. When customers are managing users features available are password policy, enforced 2-factor authentication, and new innovation for authen-

tication enforcement in the form of hardware security keys. (Google Cloud Platform, 2017)

### Summary of PaaS products

The requirement criteria of the airline company were identified and described in the previous section based on the interviews with the architects and their response given in the questionnaire. The selected PaaS products were chosen after carefully reviewing their features with the company's requirement criteria. The requirement criteria and the product features are analysed in the table below (see Table 2):

Features	Amazon AWS	Microsoft Azure	Google Cloud Platform
PaaS Product	Beanstalk	Cloud Services	App Engine
Scalability	Offers built in load-balancer, auto scaling of application server	Offers built in load-balancer, auto scaling of application server	Offers built in load-balance, auto scaling of application server possible
Vendor Lock in	Portability of applications, but locked to AWS infrastructure. Easy to migrate.	Portability of applications possible and easy to migrate	High risk of vendor lock in, portability not easy
Location	US East, US West, South America, Canada, Europe, Asia	Americas, Europe, Southeast Asia and Asia Pacific	North America, Europe and Asia
Security	Built-in SSL with extensive IAM framework	No SSL; provides Azure Active directory for identity and access manage control	SSL supported with purchase and Cloud IAM support
Languages and Framework	Java (Apache Tomcat), PHP(Apache HTTP),Node.js(Ngnix),.Net(MS IS),Python(Apache HTTP server)	Java, Ruby, PHP, Node.js, Python, Javascript	Python, Java, PHP, Go, Spring
GUI	Supported	Supported	Supported
CLI	Supported	Supported	Supported
Pricing	Free tier for Beanstalk; with 750 hours of EC2 usage, load balancing for twelve months	Different prices for different instances ; A0 instance,1cores,1GB RAM, 20 GB disk size costs €0.0169/hr	Free usage with quota ; once exceeds quota charges are applied
Pricing model	Usage based model	Usage based model	Account level dependency

*Table 2: Summary of possible advantages of PaaS products*

In Table 2 above, all the 3 major PaaS providers' features were listed based on the study on these products. The first key parameter listed is scalability; all 3 products have good auto scaling features on the application level. On the vendor lock in, all 3 products have limitations and restriction with their solution. But Amazon and Microsoft provide easy set of tools for transferring code while Google make it hard and difficult. On the data centre location, both Amazon and Microsoft have very comprehensive centres across the globe. While Google have reasonable data centres on key locations, but still lacks behind others.

From the security point of view, all the 3 PaaS providers have comprehensive set of tools and features. Amazon provides support for custom domains with self-generated certificates as part of their platform, which is advantageous and cost effective. In the Languages and Frameworks factor, Amazon has the support for maximum number of languages supported when compared to Microsoft and Google. Microsoft comes second and does support quite a good set of languages. Amazon stands out in maximum number of Operating system and databases too.

For pricing, Amazon provides a free tier beanstalk with 750 hours of EC2 usage, whereas Google provides free quota to begin with. Charges applied post this free usage with predefined models. In terms of various models for pricing, Amazon provides a wide range of model and flexible. Microsoft provides wide range of instances with various set of configurations as part of their Azure app service plan. The pricing is directly defined by the instance chosen and usage. Microsoft too provide free tier which is available for customers to deploy up to 10 apps with memory and storage capped to 1 GB.

Amazon and Microsoft provide CDN solutions as part of their offerings such as Amazon Cloudfront and Azure CDN, whereas Google has limited CDN features. Single sign on access control feature is well supported by Amazon and Microsoft through their own products. All the players support both GUI and CLI based support for application development, deployment and management.

PaaS adoption has been on the rise consistently and more organizations are evaluating to adopt PaaS solution. All the 3 major players have great set of features which caters various needs based on the need and requirements of the companies. These players

already provide IaaS service as part of their offerings, which makes it easier for organization to adopt PaaS. Most organizations look up to cloud computing as an Infrastructure offerings at the initial phase of adoption. Organizations needs lot more maturity in adopting PaaS solution for developing and deploying applications.

## 4 Existing Cloud Selection Framework

This chapter continues to collect more data in the form of literature study. Yin confirms that "A major strength of case study data collection is the opportunity to use many different source of evidence. The use of multiple source of evidence in a case study research allows researcher to address a broader range of issues. Thus, any case study finding or conclusion is likely to be more convincing and accurate if is based on several different sources of information."(Yin, 2014).

### 4.1 Importance of E-commerce in Airline

This section explores how the e-commerce division is important to an airline and what advantages this division could gain using cloud computing.

According to International Air Transport Association (IATA) on a typical day millions of people worldwide will board a commercial airline flight. To market and sell their services, airlines conduct business in a fragmented, complex distribution environment. The growing use of the Internet by travelers who shop, plan, and buy airline flights online shines a glaring light on the challenges airlines face in distributing their content. The world's airline passengers are online citizens, who are increasingly turning to the web for their travel planning, booking, and servicing -- and expect airlines and their authorized intermediaries to be able to take care of them in their digital channels. Travel is the largest e-commerce category, led by airline ticket sales. Airline websites will produce 59% of booking volume by 2017, up from 35% in 2012 (Henry, 2012). To cater such a large airline category, new and efficient technology must be adopted.

Cloud computing is the hottest trend in corporate computing right now and air transport companies should not be slow to grasp the opportunity. Airlines are constantly struggling with huge quantities of data in complex environments, and global staff require 24/7 access to data in order to keep ground and air operations running seamlessly. In an industry that reaches the globe and never sleeps, international commercial airlines need all the responsiveness and resiliency that they can get. What technology would be a better fit than cloud computing asks, Rick. (Rick, 2015)

According to Rick, the cloud gives the aviation industry an opportunity to reinvent the way airline, redefine the way it works with its customers, and rewrite its relationship with all its stakeholders.(Rick, 2015).

## 4.2 PaaS Overview

A Platform-as-a-Service (PaaS) cloud provides a toolkit for conveniently developing, deploying, and administering application software that is structured to support large numbers of consumers, process very large quantities of data, and potentially be accessed from any point in the Internet. (NIST, Badger et al, 2012)

Société Internationale de Télécommunications Aéronautiques or SITA states SaaS, IaaS, and PaaS each in its own way is capable of bringing about radically new ways of working that are particular to the air transport industry's operations. And according to Benoit Verbaere, director of SITA's ATI Cloud, "The industry's requirements are unlike many others," and the delivery of much-needed industry software through new cloud models is already bringing great advantages and it promises even more."(SITA, 2017).

To support this Badger et al., confirm that, unlike the case of a traditional system, PaaS provides a basis for developers to create scalable applications. Applications for a public PaaS cloud can: (1) employ large quantities of computing resources as needed, (2) process large volumes of data as needed, (3) be deployed nearly instantly, (4) relieve consumers of numerous IT chores, and (5) be purchased incrementally, by paying ongoing usage fees instead of traditional up-front costs for equipment and IT staff training. (NIST, Badger et al, 2012).

PaaS advantages can be listed by taking cases when companies are not using PaaS solutions, first of all developers have to wait for the development platform to be acquired, desired software to be installed and then start developing. When different/large computing resources are required, then a request is made and developers have to wait till their new configuration is provisioned. In PaaS, the cloud provider controls the more privileged, lower layers of the software stack. The operating system and hardware; implicit in this is control over networking infrastructure such as LANs and routers between data centers. At the middleware layer, the provider makes programming and

utility interfaces available to the consumer; these interfaces provide the execution environment within which consumer applications run and provide access to needed resources such as CPU cycles, memory, persistent storage, data stores, data bases, network connections, etc. The provider determines the programming model, i.e., the circumstances under which consumer application code gets activated, and monitors the activities of consumer programs for billing and other management purposes. (NIST, Badger et al. , 2012).

### 4.3 Existing Conceptual Framework

The focus of this section is to explore the existing conceptual framework and Camp ascertains that a conceptual framework is a structure of what has been learned to best explain the natural progression of a phenomenon that is being studied. (Camp, 2001).

Though there is a lot of relevant literature concerning cloud model adoption, there is not much on organizations choosing PaaS or PaaS criteria. The literature chosen for the study suggests criteria based classification for IaaS, which is more relevant to this thesis.

According to Repschläger J et al., cloud computing has become a fast growing and non-transparent market with many small and large providers, each of them having their specific service model. That makes it difficult to compare the providers as such and their service offerings. In the majority of cases the service portfolios are heterogeneous and combined with complex pricing models and service features. The customer is confronted with the situation to select an appropriate provider to realize his specific requirements mostly based on diffuse classification criteria. Due to the lack of adequate possibilities of comparing a Cloud provider, they focus on developing a classification for IaaS providers (Repschläger J et al., 2011).

Repschläger J et al., focus on developing a classification model to reduce entry barriers and support the migration into the Cloud. They have examined cloud computing from different perspectives such as technological, business issues, applications and general aspects. They define, six target dimensions based on a literature review and interviews conducted with five experts from four different companies, holding different positions



and who are important for the selection process. Repschläger J et al., also state that target dimensions serve as strategic objectives regarding Cloud Computing and provide a structure for Cloud characteristics. Next they gather all requirements available and appropriate classification criteria for Cloud providers and review them in cooperation with the experts. Based on the above they have developed a classification model by assigning relevant provider and service requirements to the target dimensions using a four level hierarchy. (Repschläger J et al., 2011).

The six target dimensions: cost, flexibility, scope and performance, reliability and trustworthiness, IT security and compliance, service and cloud management, were defined to group and structure the cloud characteristics. Each target dimension represents a general objective which the customer pursues and which characterizes his Cloud or IT strategy. Four target dimensions (costs, IT security and privacy, scope and performance, reliability and trustworthiness) were defined together with the experts prior to their analysis. Through their literature review and market research, they have validated four dimensions and simultaneously discovered two additional dimensions: flexibility and service and Cloud management, which were evaluated subsequently by the experts as well. Also it was discovered that practitioners mainly deal with questions about security, reliability and manageability of Cloud Computing. Largely unnoticed, however, remain so far the performance as well as the cost / price models (Repschläger J et al., 2011). Figure 11 below shows the six target dimension assigned to relevant sources.

Target Dimension \ Source	Flexibility	Costs	Scope & Performance	Reliability & Trustworthiness	IT Security & Compliance	Service & Cloud Management
<b>Academic Publications</b>						
Günther et al. (2001)		■ ■ ■ ■	■ ■ ■ ■		■ ■ ■ ■	
Hilley (2009)	■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■	
Hoefer and Karagiannis (2010)	■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■	
Li et al. (2010)	■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■			
Prodan and Ostermann (2009)	■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■
Anney (2010)				■ ■ ■ ■	■ ■ ■ ■	
Vaquero et al. (2009)	■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■
Peng et al. (2009)	■ ■ ■ ■		■ ■ ■ ■	■ ■ ■ ■		■ ■ ■ ■
Weinhardt et al. (2009)	■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■			■ ■ ■ ■
Hay et al. (2011)	■ ■ ■ ■				■ ■ ■ ■	
Marlens et al. (2010) (2011)	■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■
Christmann et al. (2010)				■ ■ ■ ■	■ ■ ■ ■	
Tsvihun et al. (2010)	■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■		■ ■ ■ ■	
Armbrust et al. (2010)	■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■	
Iyer und Henderson (2010)	■ ■ ■ ■					■ ■ ■ ■
Anandasivam and Prem (2009)		■ ■ ■ ■				
Lehmann et al. (2009)		■ ■ ■ ■				
Rimal et al. (2009)	■ ■ ■ ■		■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■
Schwarz et al. (2009)		■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■	
Talukder et al. (2010)	■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■
Koehler et al. (2010) (2010)	■ ■ ■ ■	■ ■ ■ ■		■ ■ ■ ■		■ ■ ■ ■
Saya et al. (2010)	■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■	
Narasimhan et al. (2011)	■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■
Russell et al. (2010)				■ ■ ■ ■		

Popularity	36	41	35	30	29	14
<b>Industry Publications</b>						
BITKOM (2010)	■ ■ ■ ■	■ ■ ■ ■		■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■
BSI (2010)	■ ■ ■ ■			■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■
EuroCloud (2010)	■ ■ ■ ■			■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■
ENISA (2009)	■ ■ ■ ■			■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■
CSA (2009)	■ ■ ■ ■			■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■
SaaS EcoSystem (2011)	■ ■ ■ ■			■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■
DMTF (2009) (2010)	■ ■ ■ ■				■ ■ ■ ■	■ ■ ■ ■
OpenCloudManifesto (2009)	■ ■ ■ ■					■ ■ ■ ■
T-Systems (2008)	■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■		■ ■ ■ ■	
Experton Group (2010)	■ ■ ■ ■	■ ■ ■ ■				■ ■ ■ ■
The Open Group (2009)	■ ■ ■ ■	■ ■ ■ ■			■ ■ ■ ■	■ ■ ■ ■
<b>Popularity</b>	<b>21</b>	<b>6</b>	<b>1</b>	<b>24</b>	<b>27</b>	<b>18</b>

■ ■ ■ ■ Low priority    ■ ■ ■ ■ Average priority    ■ ■ ■ ■ High priority

Figure 11: Six target dimension, results of literature review

Each dimension can be explained as follows:

**Flexibility:** According to Repschläger J et al., one of the advantages associated with cloud computing in science and industrial field is flexibility. When the requirements of resources vary they can be allocated and de-allocated. The resources can be provisioned in short time compared to that of traditional outsourcing and with a small overall commitment time to the vendor. The authors also suggest that other aspects such as standardization (e.g., API), the traceability of data, the short-term contracts or demand driven data needs to be considered select an appropriate vendor.

**Costs:** Monetary considerations and “pay as you go” are guidance to choose cloud computing and a particular provider. Customers who decide to cloud services gain benefits from small capital commitment, low acquisition costs for required servers, licenses or necessary hardware space and the reduced complexity of IT operations. Though there are similar services the pricing and billing models often differentiate between each provider. ( Repschläger, J et al., 2011).

**Scope and Performance:** Reacher’s insist that to select a cloud provider, knowledge about their service and performance is crucial. Also it is important to consider other features regarding performance, capacity limits (e.g. maximum number of accounts or storage space), service complexity (how many functions are available) and degree of customization (how far the service can be adapted)(Repschläger J et al., 2011).

**IT Security and Privacy:** Companies want to be sure of their data and applications meet compliance guidelines and are protected against unauthorized access when they are operated from cloud. Authors also suggest that this decision criteria refers to the service provider rather than to provided service (Repschläger J et al., 2011).

**Reliability and Trustworthiness:** Researchers says that it is important to consider commitments service provider makes in the Service Level Agreements (SLAs). And in addition the reliability is also another factor which makes SLA commitments of great importance. In contrast to the commitment, the trustworthiness describes the provider's infrastructural features, which may be evidence of a high reliability, which includes disaster recovery, redundant sites or certifications. (Repschläger J et al., 2011).

**Service and Cloud Management:** The Service and Cloud Management includes features of the provider which offer d support and functions for controlling and monitoring as

well as the individualization of the web interface. The usability of services, especially in a distributed IT architecture, and the Cloud governance, dealing with requirements and responsibilities by the customer, are essential features of this target dimension (Repschläger J et al., 2011).

### Proposed Classification Model

This classification model may help companies in their provider selection process. The dimensions are not limited to one level i.e., IaaS/SaaS/PaaS, it is for cloud computing. With the purpose of developing a classification model, similar characteristics and requirements corresponding to target dimension were summarized and mapped into three hierarchical levels, which defined abstract and operational selection criteria. The abstract and operational selection criteria were further used for structuring and differentiation purposes. In the third level of classification model, criteria have been operationalized, so that they can be compared and weighted. The fourth level defines figures and measurable requirements (Key Performance Indicator, KPI). Operative criterion of level three consists of various level four requirements. Fourth level requirements could be further divided into provider requirements and service requirements. Provider requirements describe the features of the Cloud provider independently from any service, e.g. existing certifications, IT infrastructure characteristics or the key figures of the company. Service requirements in contrast deal with characteristics directly referring to the usage of a service, e.g. service availability, scalability or interface features. (Repschläger J et al., 2011). Figure 12 below shows the classification model for IaaS.

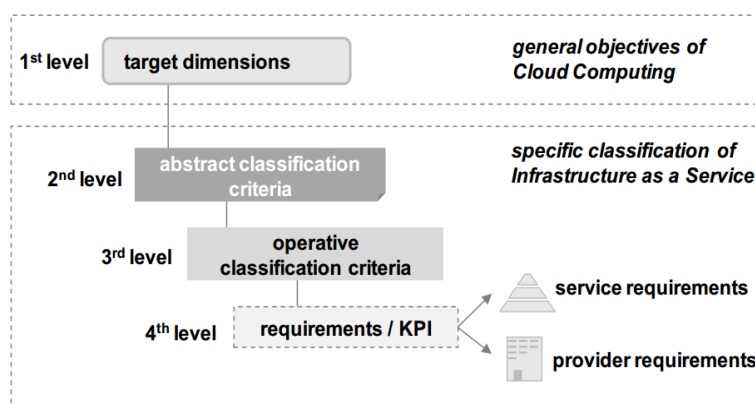


Figure 12: Classification model (Repschläger J et al., 2011).

The classification scheme offers the following example: The target dimension "Flexibility" (1st level) consists of "service dynamics" among other things, an abstract classification criterion (2nd level) which is characterized through the provisioning time (3rd level). The "provisioning time" is measured among other things by the required time to start up an instance (4th level; KPI). For instance, if the deployment time is less than five minutes, the provisioning time is rated as low, assuming the other requirements will be rated similarly. (Repschläger J et al., 2011).

Final framework and model: Repschläger J et al. finalize their paper as a classification model with six target dimensions, 17 abstract selection criteria and 51 operative selection criteria. For reasons of clarity the requirements on level four are not shown. Figure 13 displays the final framework by Repschläger J et al.



Figure 13: Selection model of Repschläger J et al.(2011)

In the above model (Figure 13), the abstract classification for flexibility is interoperability and portability, automisation degree and service dynamics. Next the key abstract

classification criteria and operative selection criteria are analysed and they are explained in terms of PaaS.

**Interoperability and Portability:** Interoperability on the PaaS level implies simple exchange of data and services among different platforms hosted on different infrastructures on cloud, and their effective reuse without extra effort on part of the user. Analysis of the interoperability of services to be hosted in different cloud platforms raises the question of portability. For example, to transfer a service from one cloud to another that uses a different platform, initiates a lot of portability problems. If the origin and target clouds use the same environment, then a simple packing and copying procedure can be used to realize the porting process. In case of different platforms on the origin and target clouds, one has to start a different transfer procedure that consists of packing, copying, instantiating, installing, deployment and customization to enable interoperability. (Magdalena et al., 2016).

**Data portability:** Data portability is the difficulty developer's face when having to extract their data and programs from one cloud platform to run. Such problem can be seen mostly in the PaaS scenario: in order to take advantage of a very flexible cloud architecture, the applications have to be specifically developed for the chosen platform. (Elias Adriano Nogueira da Silva et al., 2013)

**Scalability:** Scalability is the ability of a cloud layer to increase its capacity by expanding its quantity of consumed lower-layer services (Sebastian et al., 2016). There are two primary approaches to scaling:

- Vertical scaling, or scaling up, means increasing the capacity of individual nodes through hardware improvements, e.g., change to other nodes with higher memory, or increase the number of CPU cores.
- Horizontal scaling, or scaling out, means increasing the overall application capacity by adding more nodes. Each additional node typically has the equivalent memory and CPU capacity. (Huanhuan et al., 2014)

**Price model:** Pricing is the process of determining what a service provider will receive from an end user in exchange for their services. Different service providers employ different schemes and models for pricing. However, the most common model employed in cloud computing is the "pay-as-you go" model. Customers pay a fixed price

per unit of use. Amazon, considered the market leader in cloud computing, utilizes such a model by charging a fixed price for each hour of virtual machine usage. The “pay-as-you-go” model is also implemented by other leading enterprises such as Google App Engine and Windows Azure. Another common scheme employed by these leading enterprises is the “pay for resources” model. A customer pays for the amount of bandwidth or storage utilized. Subscription, where a customer pays in advance for the services he is going to receive for a pre-defined period of time, is also common. (May et al., 2013).

Performance: According to Chris’s blog PaaS performance metrics can help customers benchmark benefits, encourage adoption across the organization, and justify continued investment. PaaS performance metrics can be divided into three groups that correlate with maturity categories: foundation, optimize, and transform. Foundational PaaS performance metrics focus on time to market. The key metrics include:

- Time and effort to create new application environment
- Time to redeploy application
- Time to promote application into a new lifecycle phase

Optimization PaaS performance metrics focus on portfolio efficiency. The key metrics include:

- Ability to dynamically right-size infrastructure and elastic scalability
- Ability to re-use existing platform services and business services from resource pool instead of re-building solution stack

Transformational PaaS performance metrics focus on productivity. The key metrics include:

- Time and effort required integrating business process, event processor – creating a complex app.
- Time and effort required to apply policy across tenant(s)
- Cost to operate application per user or transaction measured against the value provided by the application or transaction.( Chris, 2013)

**Data Protection and Compliance:** It is very important for the PaaS service to ensure the data integrity, privacy and protection. For this purpose, several service providers are using different policies and mechanism that depend upon the nature, type and size of data. Examples of these compliances are as follows. – Health Insurance Portability and Accountability Act (HIPAA), Federal Information Security Management Act (FISMA) ,Sarbanes Oxley (SOX).

These compliances impose various requirements on data security. In a cloud computing environment, following the compliances can be challenging due to the cloud characteristics, e.g., multi-tenancy, Internet-based services, etc. Certain security certification and/or accreditation of the cloud service provider can be required before the sensitive data can be stored in the cloud. Such a security certification usually involves comprehensive assessment on the service provider with regard to its operational and/or technical security controls. For example, FISMA requires such a certification/accreditation before the agents can utilize cloud services for data processing/storage. Whenever necessary, strong data protection such as cryptographic mechanism should be employed to provide information confidentiality, integrity, availability, and more. Data access should be audited to help detect inappropriate disclosure and/or modification of data. Attention should also be paid to the geographic location of data storage, which can be regulated by the export control regulations.( Shucheng et al., 2010)

**Service-Level Agreements:** Hassan et al states that, "The on-demand service or utility-based economic model necessitates the use of well-established service level agreements (SLA). An SLA is a part of a service contract between the consumer and provider that formally defines the level of service. It records a common understanding about services, priorities, responsibilities, guarantees, and warranties. In cloud computing, SLAs are necessary to control the use of computing resources. Therefore, the main issue for cloud computing is to build a new layer to support a contract negotiation phase between service providers and consumers and to monitor contract enforcement. Unfortunately, security, privacy, and trust are inherently non-quantitative and difficult to bargain, but there should still be ways to assure customers that services are provided according to what a service provider claims in the contract. The dynamic nature of the cloud necessitates continuous monitoring of attributes to enforce SLAs. Consumers might not completely trust measurements provided solely by a service provider, which



might require agreed-upon third-party mediators to measure the SLA's critical service parameters and report violations".(Takabi et al., 2010)

**Incident and Service Management:** In cloud computing Incident Management provides a solid approach to address SLA incidents by covering aspects pertaining to service run-time in cloud through monitoring and analysis of events that may not cause SLA breaches but may disrupt service execution. It also covers aspects related to security by correlating and analysing information coming from logs and generating adequate corrective responses (Victor et al., 2014). Thus cloud incident and service management is important factor to be considered when designing framework.

In this chapter various literature on topics concerning cloud computing, airlines and PaaS was covered. Also literature concerning conceptual framework based on target dimensions, abstract classification criteria and operation classification criteria was explored. Other researchers' understanding on certain abstract classification and operations were also examined. In the next chapter the data collected so far is analysed and the building of the conceptual framework is explained.

## 5 Current State Analysis

Though there are other sources from which data are collected, this set of data is about existing Information and Technology (IT) platform of the e-commerce and customer experience department of the airline company. The data were collected through series of interviews and the results are presented in detail. The drawbacks derived from the company's current challenges are also discussed.

### 5.1 Questionnaire Outcome and Analysis

In this section, the existing Airlines IT architecture is analysed and the challenges are identified. In order to evaluate the existing architecture and platforms, a questionnaire was created and distributed. The aim of the questionnaire was to gather information regarding the existing architecture, current development and deployment its strengths and weakness practiced in the e-commerce department. Participants of the interview are two specialists in charge of architecture, with extensive experience: Airline Technical Architect and Solution Architect. The interview was conducted semi-formally. Initially, the questionnaire was sent out by email to the participants and then a verbal conversation was held through mobile phones and messenger chats. The present study tries to summarize the airlines' problems in general as the participants have experience with one or more airlines. The original contents of the questionnaire can be seen in Appendix 1.

The questionnaire had a different set of questions in the following categories:

- E-commerce department
- Features of development and hosting environment
- Integration
- Languages and frameworks used

## Summary of Questionnaire

The first sets of questions were to understand the e-commerce and customer experience department. Both the architects gave their valuable information on the topic and their explanations are summarized as below.

The e-commerce for airlines is on the most highly demanding areas with changes, developments and new features are a daily need. Some of the key developmental activities are related to product selling, product promotions, customized product selection and other web development activities. Any changes on the website also have significant integrations with various systems which are part of e-commerce division. For better understanding e-commerce division is explained in following sections.

## 5.2 Architecture Overview

In this section the logical architecture related to e-commerce and Cx will be explained and analysed in detail. Figure 14 shows the logical architecture of the airline e-commerce department.

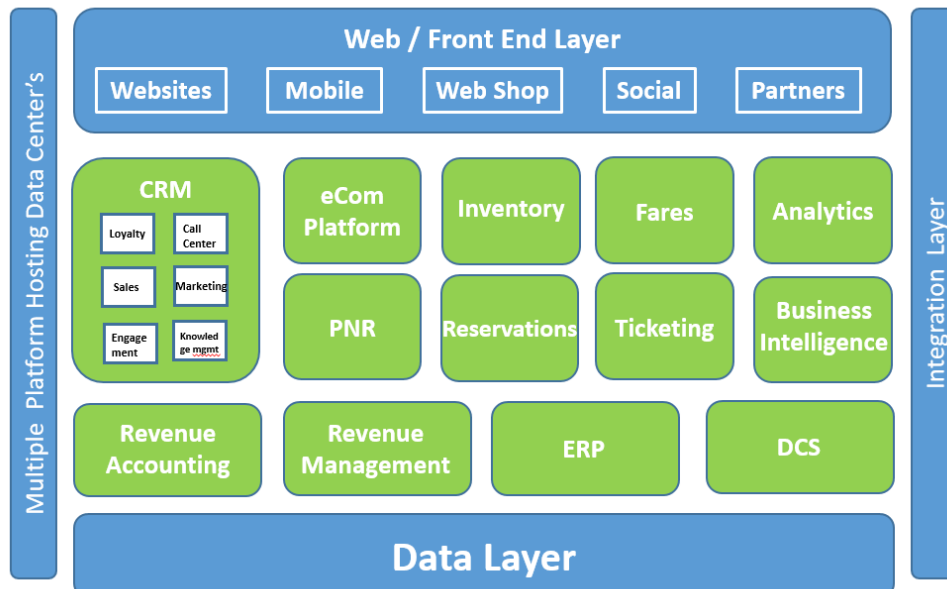
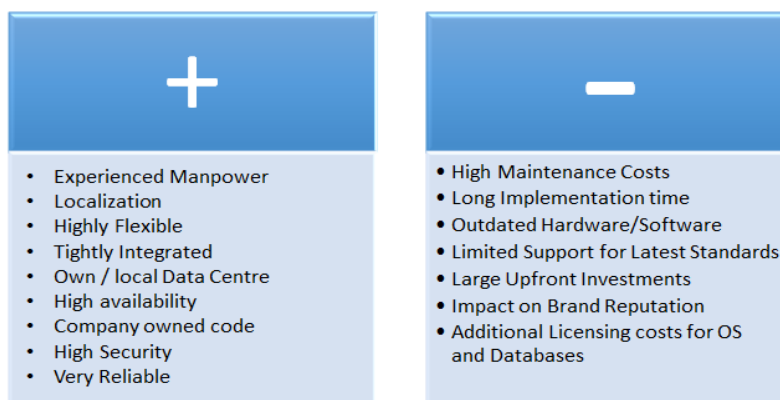


Figure 14: Airline e-commerce Logical Architecture

The above Logical architecture (Figure 14), explains the various layers within the e-commerce and Customer experience area in an airline architecture. The five major layers are the Web/front-end layer, Application/systems layer, Data Layer, Integration Layer and Hosting layer. The key focus of the present study is the Hosting Layer, Application/System layer, and Data Layer. The purpose and significance of these layers in the architecture are explained in the coming sections.

The applications/systems layer covers a range of systems and functionalities for an airline, such as Customer Relationship Management (CRM) area which includes Sales, Service, Marketing and Engagement features. Other prominent areas include E-commerce platform, Business Intelligence, and Analytics, which requires heavy processing and a huge amount of records handling.

The data layer is one of the most important layers in the architecture and has gained significance over the past decade. Airlines have been facing huge challenges in Customer data management, Customer retention, and personalization. Airlines are focusing on managing the data effectively to build personalized sales, service, and marketing, which in turn helps in building brand reputation. Data processing has evolved over a period, where the customers are not necessarily interested in transactional or operational data alone. Customers need has increased exponentially, needs to have personalized offers, real time decision assistance, suitable products, and much more. The on-premise model has its own advantages and disadvantages, which will be analyzed in the next section. Figure 15 shows the plus and minus of the on-premise architecture.



*Figure 15: Plus and Minus of existing on premise architecture*

Figure 15 helps to further explain the pluses and minuses of the on premise architecture. Most airlines own a traditional on-premise model i.e. most applications/systems are hosted in their Own Data Center or 3rd Party data center. This on-premise model provided airlines to have complete control over their systems and has helped them keep it more secured. But the growing demands and digitalization across the globe, has forced the organizations to rethink on their existing on-premise model and pave a path to new Cloud architecture.

The e-commerce area has various on-premise applications running on proprietary software, has resulted into complex technical integration architecture. It is challenging for the business to introduce new enhancements into the system. Considering the challenges in the current system and implementation, the company is looking for a flexible and dynamic solution to address their business needs effectively.

### **Roadmap for future**

Further questions were posed to the architects on their plans for digitalization and improving their existing solution. Their comments are summarized as below.

The airline company wants to simplify the software license management and maintenance and also wants to simplify the deployment process by focusing more on developing the application software. And as a part of digitalization, the company is considering to move towards cloud solutions. Also, architects are of the opinion that cloud computing will address the business needs effectively and keep the technical implementation simple and efficient. The case company requires following criteria to be present in the cloud model: Agility, Cost efficiency, Scalability, High Availability, Vendor lock-in, Security, Framework and languages support. Table 3 consolidates the summary of the requirements.

<b>Criteria</b>	<b>Description of Criteria</b>
Flexibility	The ease at which hardware resources can be set up for development and deployment
Cost	Efficient hardware resource management ;shorter development and deployment reduce cost
Scalability	Capacity of resources to grow and shrink as per the demand
Security	Ability to deal with risks and threats;

Languages supported	Developer tools, Application technologies and runtime configurations provided for the developers
High Availability	Application downtime should be minimal with disaster recovery
Vendor Lock-in	Applications can be moved to another platform without any influence of Vendor lock-in

Table 3: Summary of requirements

The detailed explanation of the requirements listed above, will be explored in the following sections.

#### Flexibility

The results from interview indicate that setting up the platform to run applications are time-consuming and complex. As of now setting up environment takes weeks and months which is make business less competitive and slow. So the department wants a simplified application development and deployment solution.

#### Scalability

Developing and testing software code in existing approach is intensive and requires a large amount of hardware. Once deployment is completed this hardware lies inactive and is underutilized. This is one of the major concerns, when the hardware requires maintenance when not in use. As a result, the airline pays for underutilized resources.

#### Cost-efficiency

According to architects, current on-premise solution is not satisfactory in terms of cost. The company has invested in the procurement of large IT systems to develop and deploy their applications and not limiting to this, the company additionally has to pay for the maintenance of hardware resources, disaster recovery, networking, air conditioning and power supply and for third party Company which takes care of the above tasks. Costs incurred due to agility and scalability is also high. Also, the new cloud system has to accommodate pricing for the extrapolate data. So company puts pricing as one of the key criteria which needs to be considered.

## Security

The airline company deals with sensitive customer data and hence it is crucial for the company to put forth security criteria. Architects insisted that new cloud provider should meet data security standards of the industry. Any cloud provider having regulatory frameworks such as PCI, ISO-27xxx, COBIT, SW cert and SW security which the airline industry can rely upon, would be an advantage.

## Languages and framework support

Basically new cloud model should have a robust platform to support application development framework. Cloud model should support the data bases the current system uses. Overall the company expects support for many programming languages which will give more options and flexibility to the developers.

## High Availability

For e-commerce department, the availability of the system is very crucial and hence it is a key factor which will influence adopting the new cloud model. Here architects are interested in downtime and disaster recovery of the cloud model. In the case of downtime cloud provider's availability and Service Level agreement (SLA) should be transparent.

## Vendor Lock-in

Vendor Lock-in is also one of the decision-making criterions, for the company to decide on a new cloud service. Architects would like to have the possibility to change platforms without any locks. Also, they want the cloud providers to approach to be standardized in application portability, data storage location and a number of applications that are allowed to be developed on the cloud platform.

## 6 Building Evaluation Framework

In the previous chapters, the stage for building evaluation framework was set. The airline company's readiness to adapt cloud solution, interviews with architects, key requirements, understanding of basic and key concepts of the cloud computing, summary of major PaaS provider's features, different models to adopt cloud solutions were the building blocks for the evaluation framework. "Framework is an analytical process which involves a number of distinct though highly interconnected stages" (J. Ritchie et al., 1994). This chapter focuses on building evaluation framework for the airlines.

### 6.1 Building First Level Evaluation Framework – Target Guiding Model

In this section, the details of building the proposed evaluation framework are discussed. The evaluation framework is named as "Target Guiding Model" and it consists of two levels. The first level was derived based on interviews with Technical and Solution architects. The interviews revealed that there are certain preparations required on the organizational levels since this migration will be strategic. As a result four key focus areas were identified. The key areas that the organization needs to focus are explained below.

### 6.2 Airlines E-commerce and Cx Focus

The decision to take cloud solution as part of the digital transformation from on-premise is a big step forward for e-commerce and Cx division of the airlines. Selecting a PaaS solution is not just a technical or functional or business choice alone, it is also an organization's choice and decision. Most airlines with the diverse set of applications, vendors, and processes have made it extremely complex to adapt to common platforms and frameworks. Table 4 shows the focus areas and actions required to be taken as an organization.



<b>Focus Area</b>	<b>Needed Actions</b>
IT Strategy	Clear vision, goal and strategy for a PaaS solution for the organization.
Organization	The airlines must reorganize hierarchies and positions of their organizations in order to ensure that the managing of platforms and frameworks are easier.
Scope management	The airlines need to define a clear scope and limitations for the areas where PaaS solution will be considered.
Decision making	Key stakeholders and responsibilities should be well defined for clear decision making

Table 4: Focus Area and Needed Actions

Above (Table 4), some of the most key focus areas for the airlines have been listed in order to streamline their internal organization and enable easier decision making on the PaaS solution. The airlines need to focus on four key areas as an organization preparing to select and use a common PaaS solution. The key areas are: IT Strategy, Organization, Scope Management and Decision Making.

### 6.3 Building Second Level Evaluation Framework – Target Guiding Model

In this section, the details of the second level evaluation framework are discussed. A systematic literature review was conducted in order to create second level of the framework. With the literature review, target groups were created and criteria were gathered to match respective target group. The final outcome were five target groups, each includes relevant classification criteria. For airlines, in order to choose a PaaS solution, it is important to have clear selection classifications and related criteria. The key classifications or target groups proposed as part of the model are:

- a. Business Value and Strategy
- b. Data Storage and Protection
- c. Technology and Performance
- d. Development and Deployment
- e. Management and Operation

In the next section, these classifications and related criteria will be explained in detail with respect to the airline industry.

#### 6.3.1 Business value and Strategy

The first classification or target group in the proposed model is Business value and strategy. For the airlines to be successful in selecting a right PaaS, it is important to focus on criteria which helps and adds value to their business and their strategy. Key criteria which are part of this classification are:

- i. Flexibility

Flexibility is the ability to fluctuate with demands and it is a very important factor for the airlines. For example, when airline sends email campaigns for selling seats, thousands of people will be visiting the website and this requires additional compute re-

sources to address growing traffic volume on the website. While PaaS supports scaling up resources (Table of PaaS providers), it is also very important to shrink compute resources when the demand is less. This flexibility to automatically control compute and storage resources would optimize cost associated with demands that may or may not be needed.

#### ii. Multi Location

Data center locations are the vital criteria to be considered by organizations like the airlines. For the airlines, data center needs to provide performance, compliance and disaster recovery from multiple locations, without any negative impact to the business. Network latency has a significant impact in selecting PaaS solution, since the connectivity between existing applications in different data centers should interact with PaaS solution seamlessly. Another important and key factor on choosing a PaaS solution is the legal aspect. Most airlines are governed by data privacy laws based on their base location. For e.g. Airlines operate from EU expect their data center to be located with EU. So it is important to choose a PaaS solution provider who offers multiple locations.

#### iii. Elasticity

Elasticity is a key changer for business, because it allows computing resources to scale up and down instantly, which benefits business, develops their software applications in a cost effective manner. For example, Airlines bound to have planned and unplanned raise in traffic in their website for various reasons such as campaigns or natural disaster or flight delays, etc., it is important to have the feature to scale the resources on the demand basis. Also its important to have a cost effective solution, which enables Airlines to pay more for resources only on the need basis. This kind of resource elasticity will lead to change in the speed of development and time to market is also addressed.

#### iv. Pricing Model

One of the core potentials of the PaaS cloud model is that it supports development and deployment of software applications by taking care of all the hassles of installing and maintaining development platform, allowing the airline company to concentrate on

business innovations. Also a PaaS model offers to charge only for the resources used by the airline company and maintenance costs of IT hardware, electricity and cooling are also handled by the PaaS provider. By employing a PaaS cloud solution model the airline company can remove Cost of Ownership (COO).

v. Partner Eco System

A partner eco system will help in determining the range of applications and services that can be built around the eco system.

### 6.3.2 Data Storage and Protection

Next classification or target group which is part of the proposed model is Data storage and protection. The airlines passenger traffic constantly grows in volume and also new features are high in demand, due to nature of the business and industry needs. They need to pay key attention in the areas of Data Storage and Protection due to ever growing volumes in the travel industry. Key criteria's which are part of this classification are:

i. Disaster recovery

Disruptions to the airlines can occur in any form such as floods, fire accident, computer malfunctions, and hardware failures. In all such disasters, airlines face frustrated customers, loss of revenue and negative coverage about the company. Disasters have a big impact in terms of risk, cost, loyalty and tolerance for both the company and customers. Ability to recover from such disasters within few minutes would be an ideal solution without causing outages for hours and days. Hence it is very important for airlines to choose PaaS with a disaster recovery option, which guarantees high availability and resiliency for the offered services.

ii. Security

For the airline, security is the most influencing factor for selecting a PaaS provider. Large numbers of people are using the airline's website (e-commerce) to buy tickets, enroll in loyalty programs, and other activities, because many people's personal data

are gathered and stored, it is very crucial for the airlines to take care of sensitive data. It is also very important for the airline to safeguard security concerns like authentication, integrity, and non-repudiation; failing or breach in of these would be a major loss and would attract negative effect to airlines and customers. The airline should consider PaaS providers who offer strong encryption and authentication process.

### iii. Data protection and compliance

This criterion is critical with respect to the airlines since airlines passenger data deals with of sensitive personal information gathered from reservations such as mode of payment, mobile number, email address, nationality, sometimes health conditions, etc.,. The airlines have to choose PaaS providers who can assure of all the data protection, privacy, and integrity. In addition, importance should be given to PaaS provider whose systems are Payment Card Industry Data Security Standard (PCI DSS), the healthcare industry's HIPAA/HITECH compliant. Also, the location of data stored/transferred should follow adequate data protection framework.

### 6.3.3 Technology and Performance

This classification is important for the airlines. Employing new technologies means increasing efficiency, reduction in cost and improved operations. Performance is directly proportional to technology, in airlines On-time performance (OTP) or punctuality depends on the technology being used. All the advantages could become disadvantageous if the performance of the technology is not optimal. Crucial criteria to be considered are:

#### i. Public/private/hybrid cloud

One of the biggest concerns for the airlines is the security over their customer data and core applications. While moving to cloud provides them the enormous flexibility and agility, but at the same time having their servers secured and accessed privately remains a major requirements. Cloud solutions provide multiple options i.e. either public and private clouds or combination of both together (Hybrid). Private clouds are restricted and accessed only within the airlines networks (the organization which owns it) which makes it more secured and accessible via their firewalls. The airlines e-

commerce architecture needs to have a balance between both public and private cloud. Some of the services provided to end customers' needs to be available and accessible through public cloud services. At the same time, the core applications and customer data should be protected and kept behind private cloud services. PaaS providers should provide both Public and private cloud as part their solution. So that airlines have the flexibility to choose virtual private cloud along with public cloud services as part of the same PaaS solution.

#### ii. Software updates

Application deployment process is the evaluation process of development workflow. And application deployment workflow has to be efficient since a bad deployment could ruin the best development process. Some deployment failures could pose challenges and complicate development workflow.

#### iii. Auto Scaling

Auto Scaling is important with respect to e-commerce. For example, there could be high rise in traffic of the airline website, if there has been seasonal ticket offers or new aircraft is added with new routes and destinations. In order to address these types of requirements PaaS vendors need to provide auto scaling feature with scheduled deployment of instances.

#### iv. Technology Stack

Another key criterion that the airlines need to decide before the PaaS provider is selected is the usage of open source or proprietary stack. The airline needs to know about the technology stack that the cloud provider uses. This will help in determining and optimizing various factors - such as Developers/consultants available in the market for the implementation, and building interfaces with other systems.

### 6.3.4 Development and Deployment

An enabler classification: develop and deploy, which allows the propagandas to be real. Software applications developed, integrated and deployed in an easy and instant way

could be a competitive advantage. And for airlines developing software applications and releasing them to the customer on time will allow the airlines to be competitive in this evolving industry. Essential criteria's for Develop and Deploy are:

i. Ease of collaboration

Airlines business teams engage in constant conversations. For example, if the booking team wants to seek clarification regarding the development of a certain feature from the developer, they send their queries via email. In such a situation, an online collaboration feature eases communication by providing real-time feedback to the development team, also accessing, editing and sharing of documents or files are done in real-time. This will create an effectively engaged team who will focus on efficient knowledge sharing. Hence airlines should opt for a PaaS vendor which provides collaboration features in their PaaS product.

ii. Accessibility

Developers can create their own platform that suits airline's needs and they can have full control of the tools installed on that platform. Also, developers have the accessibility of working from any device that has an internet connection. Many critical developmental issues can be solved as stand-alone devices do not provide restrictions anymore.

iii. Application deployment

Application deployment criteria is one of the major purposes of PaaS solution. Most PaaS solutions provides set of services to make the web application deployments easily and able to manage the deployments efficiently. For airlines, this is crucial criteria, since there is a higher demand to deploy web applications either new or updated frequently and without any impacts on the customer usage. It is highly important to have PaaS solution which provides varied set of tools and services for easier and quicker deployments.

iv. Language and framework

Almost all PaaS providers provide multiple programming languages, frameworks, operating systems, databases, middle ware and other tools. It is always important to consider programming languages the airlines has been using already and also look for alternative programming languages that can cater the needs of the airline company. Also, it is important to have a well-defined development framework to adopt to set of programming languages which are easily transferable.

### 6.3.5 Management and Operation

The final and crucial classification is Management and Operation, once a new system is taken in to use, operating and managing becomes an essential part. The complex and varied landscape of applications of the airlines makes it even more important to ensure that the selected PaaS is easy to operate and manage. Mandatory criteria's for this classification are:

- i. Document control

If the Platform doesn't provide any version control mechanism for the source code and the metadata components it needs to be implemented outside the application/platform which makes deployment difficult. Regulated industry like airlines, require version control for regulatory reasons. Currently due to the larger number of developed features rollbacks are an issue and version control becomes important in these cases.

- ii. Maintenance and upgrade

The airline business being one of the demanding industry maintenance and upgrades of the current systems are bottlenecks faced by development team. Auto upgradable environments to the latest release of the platform and easy maintenance are provided by PaaS providers. It is important for airlines to find one such provider.

- iii. Cloud breakup and Vendor Lock in

The airline company which involves huge amount transactions, various set of applications, numerous amount of activities through websites and other channels, requires extremely agile and easily transferable or reusable or extensible software and hard-



ware systems. Based on the dynamic and growing demand, airlines need to adapt to new technologies and software's more often than other industries. It is important to have cloud computing solutions which can be transferable without much constraint on following aspects like cost, legal, technical and work efforts.

#### 6.4 Summary on Proposed Evaluation Framework

The Target Guiding Model outlines criteria the airline company needs to consider before choosing right PaaS solution. The framework also outlines the key focus areas for the airlines to consider from the organization point of view. Effective application of the framework model will give the airlines company clear assessment of the numerous PaaS solutions available. The classifications and criteria discussed in the framework provide the airline company an insight into how right PaaS provider would be a value addition for a strategic business. Evaluation framework was based on data collected in various interviews, and literature study. After careful review and analysis, the comprehensive framework for selecting PaaS was derived and the final proposed framework presented below. Figure16 represents the Target Guiding Model.

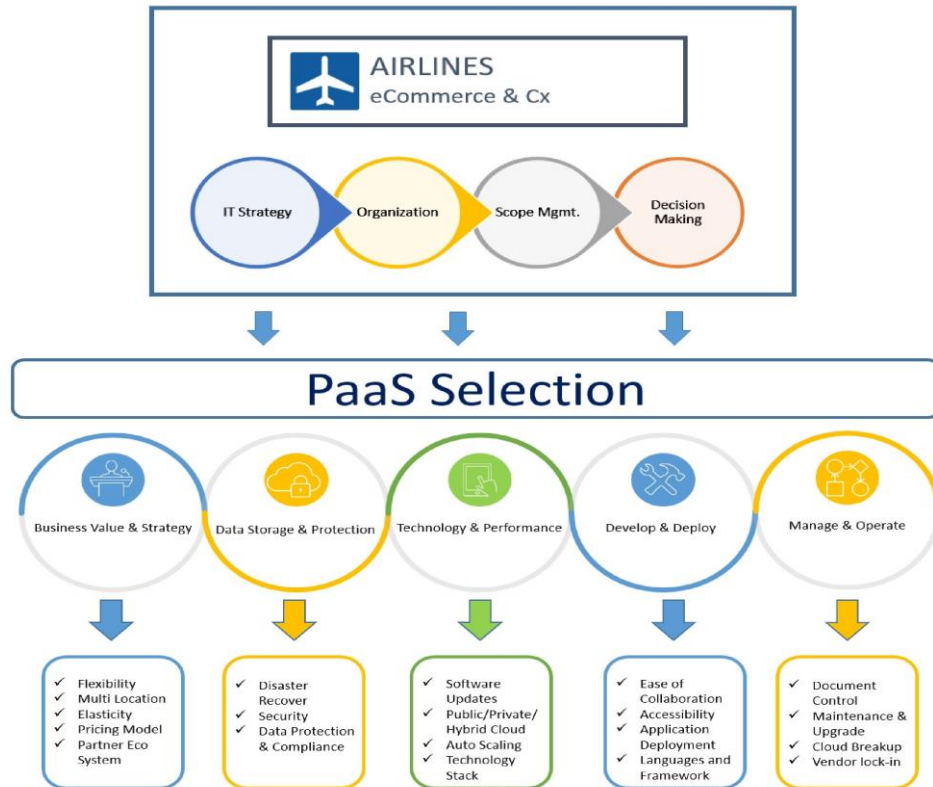


Figure 16: Target Guiding Model

To support the migration into the PaaS, the proposed Target Guiding model was derived. Also, the five target group meets the requirements of cloud computing characteristics and serves as the strategic objectives of PaaS.

## 7 Evaluation of Framework and Conclusion

The next step in this thesis is to evaluate the newly built PaaS selection framework. The framework was shared with the experts, i.e. both Solution architect and Technical architect, to get their respective feedback and execution of the framework in the case company, in order to select a PaaS solution for the airline's e-commerce and Cx division. The review was done for both the airlines e-commerce/Cx focus areas and PaaS selection classification and criteria.

### 7.1 Airline E-commerce and Cx Focus

Feedback on the airline e-commerce and Cx focus areas was collected based on a face to face workshop. The architects suggested these focus areas were the most needed in order for the airlines to organise themselves before selecting PaaS, also due to the fact that there is a more diverse set of applications and owners within the airline team. It is important to have a strategy at the division level, in order to have a single vision on the platforms and solutions. Organizations and hierarchies needs to be streamlined to make the decision making more efficient. Currently the divisions have isolated and mainly concentrated decision makers within the division. Another key factor, i.e. scope management needs to be planned and defined in phases. Moving to a PaaS solution means a massive set of applications, moving existing code and migration needs to be planned. The scope should be well defined with risks and phases, in order to make the transition and migration easier and manageable.

### 7.2 PaaS Selection

The feedback data were collected from the experts on the PaaS selection framework are described. The overall feedback on the structure of the framework was positive. The 5 classification model provides clarity and modularity in approaching the PaaS selection. These classifications also enable the airlines to look at the PaaS selection from different perspectives such as Data, Technology, Business strategy or Operations. Typically, most airlines do have various owners in managing these different classifications. It provides a clear evaluation and supports a point of view from various perspectives.

For this evaluation all the 3 products presented in the PaaS comparison were considered i.e. Amazon AWS Beanstalk, Microsoft Azure Cloud Services and Google App Engine.

### 7.2.1 Business Value and Strategy

The criteria of Business value and strategy were evaluated and the collected data were presented as part of the analysis. The initial finding from the evaluation is that in overall all the three products equally do well in these criteria. But Amazon AWS and Microsoft Azure score relatively better over the Google App Engine in many areas. Amazon and Microsoft have a number of instance templates almost double the numbers what Google can offer. At the same time, google offers custom instance creation which others don't have. In the multi-location option, both AWS and Azure get an advantage as they offer more options for location and freedom of deciding the locations. Flexibility and partner ecosystem evolve together and they are evaluated together, AWS is more advantageous with respect to Microsoft and Google. Table 5 shows the overall summary of Business value and strategy evaluation.

<b>Criteria</b>	<b>Amazon AWS</b>	<b>Microsoft Azure</b>	<b>Google Cloud</b>
Flexibility	Yes	Yes	Yes with limitations
Multi Location	Yes	Yes	Limited locations
Elasticity	Yes	Yes	Yes with limitations
Pricing Model	Flexible models	Flexible models	Limited pricing models
Partner Eco System	Yes	Yes	Yes with limitations

Table 5: Summary of Business value and strategy evaluation

In the above Table 5, PaaS providers with respect to criteria related to Business value and strategy are listed. From the analysis, Amazon and Microsoft do well overall. From the importance factors such as flexibility and partner eco system, Amazon is more advantageous.

### 7.2.2 Data Storage and Protection

The next set of criteria, part of Data storage and protection classification, were evaluated and collected data were presented as part of the analysis. Organizations mostly own or need custom domains for their cloud solutions, which should be accessed via secure sockets layer (SSL). Amazon provides feature to generate own certificates for custom domain for free, whereas others expect certificates from certificate authorities or custom generated. Disaster recovery being one of the most key criteria, all cloud services are well equipped and provide well managed solutions. Data protection and compliance are one of the major considerations for any customer operating in the EU. All the three providers have data centers inside EU and provide the necessary compliance for data. Table 6 shows the summary of Data storage and Protection evaluation.

<b>Criteria</b>	<b>Amazon AWS</b>	<b>Microsoft Azure</b>	<b>Google Cloud</b>
Disaster Recovery	Yes	Yes	Yes
Security	Yes	Yes with limitations	Yes with limitations
Data Protection and Compliance	Yes	Yes	Yes

Table 6: Evaluation summary of Data storage and Protection.

In the above table 6, the summary of the evaluation of 3 PaaS providers with respect to criteria related to data storage and protection is listed. While all the 3 PaaS providers manage and adhere data protection and data recovery part very well. Amazon outweighs competition due to easy and flexible security features.

### 7.2.3 Technology and Performance

Another set of criteria is part of Technology and performance classification, were evaluated and collected data were presented as part of the analysis. Auto scaling is relatively easier in Amazon and Google when compared to Microsoft azure which has some limitations due to tier changing. Amazon provides GPU acceleration which is advantageous when compared to other players. Amazon supports more databases and supports more operating systems than others. Both Amazon and Microsoft provides private cloud possibility as part of the cloud solution. This enables airlines to have both public

and private cloud at the same time as part of one PaaS solution, makes it more flexible. For the airlines, the auto scaling is critical due to planned and unplanned volumes in web application usage. Having both public and private cloud feature is also critical since it provides complete control over the apps and data exposed to public networks. Table 7 shows the summary of the Technology and Performance evaluation.

<b>Criteria</b>	<b>Amazon AWS</b>	<b>Microsoft Azure</b>	<b>Google Cloud</b>
Software Updates	Yes	Yes	Yes
Public/Private/Hybrid Cloud	Yes	Yes	Yes with limitations
Auto Scaling	Yes	Yes	Yes with database scaling
Technology Stack	Yes	Yes	Yes

Table 7: Summary of Technology and Performance evaluation

In the above table7, the summary of the evaluation of 3 PaaS providers with respect to criteria related to technology and performance is listed. Both Amazon and Microsoft stands out from Private cloud and features associated. Similarly Amazon and Google provide the most flexible Auto scaling features. Overall the advantage relies with Amazon on all the criteria.

#### 7.2.4 Development and Deployment

The criteria are part of Develop and deploy classification, were evaluated and collected data were presented as part of the analysis. As far as languages and frameworks are concerned, Amazon stands out with maximum number of languages and frameworks supported, whereas Microsoft comes next. Ease of collaboration both Amazon and Microsoft do well with good support to collaborate with other systems and networks. Google cloud offers easy deployment of web applications with free and quicker deployment, but others provide complete control over OS and system. From an airlines' perspective, ease of collaboration and application deployment are important factors due to the fact that the application landscape and partner landscape is wide. Also the application deployment point of view, the cloud services should provide complete flexi-

bility in control over deployment and modification. Table 8 shows of the summary Development and deployment evaluation.

<b>Criteria</b>	<b>Amazon AWS</b>	<b>Microsoft Azure</b>	<b>Google Cloud</b>
Ease of collaboration	Yes	Yes	Yes with limitations
Accessibility	Yes	Yes	Yes
Application deployment	Yes	Yes	Yes with limitations
Languages and Framework	Wide ranges supported	Wide ranges supported	Limited ranges supported

Table 8: Summary of Development and Deployment evaluation

In the above table 8, the summary of the evaluation of 3 PaaS providers with respect to criteria related to development and deployment is listed. Amazon and Microsoft provides support for maximum languages and framework. Also these 2 PaaS players provide features that support ease of collaboration.

#### 7.2.5 Management and Operation

The next set of criteria is part of Manage and operate classification, were evaluated and collected data were presented as part of the analysis. All the 3 PaaS providers have vendor lock-in with their setup, whereas Google provides open source for application development but deployment still limited with their platforms. Both Amazon and Microsoft provide easier way or tools available for migration or transferring to different platforms. Table 9 shows the summary of the Management and operation evaluation

<b>Criteria</b>	<b>Amazon AWS</b>	<b>Microsoft Azure</b>	<b>Google Cloud</b>
Version Control	Yes	Yes	Yes
Maintenance Up-grades	Yes	Yes	Yes

Cloud Breakup	Yes	Yes	Yes with limitations
Vendor Lock-in	Yes and easy transferable code	Yes and easy transferable code	Yes and limitations on transferring code

Table 9: Summary of Management and operation evaluation

In the above (Table 9), the summary of the evaluation of 3 PaaS providers with respect to criteria related to management and operation is listed. While all the 3 PaaS providers have Vendor lock in, only Amazon and Microsoft provides good set of tools for easy transfer and migrate code.

### 7.3 Summary

Based on the evaluation using the Target guiding model by the experts, the overall summary is listed in this section. Amazon Beanstalk and Azure Cloud service overall score higher on many counts when compared to Google App Engine. Amazon is slightly a better choice out of all the three PaaS solutions evaluated. Amazon PaaS provides maximum number of instance templates, OS, Databases, CPU's, languages, frameworks, and maximum temporary storage. Google App Engine proves to be cheaper and simpler pricing model. For the airlines, the benefits evaluated based on the 5 different classifications using the new Target guiding model. Amazon has the most advantages and at the same time it's also the most expensive solution out of all. On the other hand, Microsoft fairly competes well on all classifications with Amazon and has few disadvantages. Concluding the findings, Amazon Beanstalk solution stands on top of this evaluation and proves to be the most optimal choice.



## 8 Conclusion

The aim of this thesis was to develop a conceptual framework with set of criterias to evaluate and select the right PaaS solution. The framework will be applied by the e-commerce and customer experience (Cx) division of the airline company to choose the right PaaS solution.

To accomplish the goal, the qualitative research method was used and for gathering data, regular interview technique was used. The questionnaires and workshops served as the instruments for collecting data. The participants of the interview were two architects. The next set of data was collected through various literature. The requirements and data collected were analysed and the new evaluation framework Target Guiding Model was built.

### 8.1 Objective vs Outcome

The outcome of the study compares the objective of the thesis defined in the initial phase of this study against evaluation of the framework. The objective of the thesis was to develop a conceptual framework to evaluate and select right PaaS solution for the airline company. The solution was built and provided to the airline company for their feedback. The new framework is a two level guiding model. The first guiding level defines how the airlines as an organization should prepare to select and use PaaS. The second guiding level is a classification of target groups with criteria grouped to respective targets. The feedback from the architects validates that the proposed framework criteria are able to support the airlines in evaluating and choosing the right PaaS. The target group criteria of the framework cover all the requirements of the airline company and the PaaS offering can be compared easily and selection process can also be accelerated. The use of the target dimension framework provides fact -based performance selection rather than a subjective service assessment. Furthermore, the framework can guide the airline company to adopt and implement complex PaaS offerings.

## 8.2 Further Steps

In future this framework can also be used by other airlines with similar e-commerce architecture, they can apply the target guiding model to evaluate and choose PaaS offerings.

Also PaaS providers could standardize and align their solution to be in line with framework as it would help companies comparing and adopting a PaaS solution.

This framework was limited to the e-commerce division with the PaaS selection. This study could be further expanded to other divisions of airlines and also analyze the other cloud models such as IaaS and SaaS. Furthermore the framework target groups could be enhanced with more criteria which could cater other business and other cloud models.

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## Appendix

Details of questionnaire:

First of all thank you for your time and agreeing to participate in this interview. As you know that these interview questions and answers will help us to understand the architecture of the ecommerce department of the airline company. Please elaborate your views, positives, negatives and point us if there are any shortcomings in compiling questions.

### Questionnaire set 1:

Questions related to the airline organization

What is organization's strategy for adopting cloud computing?	
Will cloud solutions replace on-premise solution?	
Which departments are going to use it?	
How will the migration plan be executed? Who are the responsible people?	

### Questionnaire set 2:

Questions related to e-commerce and Cx division

1	What is organiza-	
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	tion's strategy for adopting cloud computing?	
2	Will cloud solutions replace on-premise solution?	
3	Which departments are going to use it?	
4	How will the migration plan be executed? Who are the responsible people?	
5	What comprises of e-commerce architecture?	
6	What are the features of the e-commerce department	
7	How many applications are used in this department	
8	<b>How many vendors support the department</b>	
9	<b>How are the current datacenters managed</b>	
10	<b>Different types of hosting</b>	

11	<b>How is current development and deployment done?</b>	
12	<b>How long does it take to deploy?</b>	
13	<b>What are the advantages of existing platform</b>	
14	What there development languages used?	
15	What are the drawbacks	
16	What are problems that are faced during deployment?	
17	Your experience with add-ons management(log and debugging tools)	
18	What are your expectations with respect to new development and deployments ways	
19	Which aspects or features is of utmost importance	



20	Which general properties can you consider	
21	Implementing cloud computing effect on other departments and integration	
22	Do you consider automation for future use	