Strategy for Migrating Legacy Applications to Cloud (SoMLAC)

Author
Abhinav Mohan (abhinav@kth.se)
Master of science, Software Engineering of Distributed Systems
ABSTRACT

Any modern business utilizes a number of IT-solutions for its day to day functions, for example accounting, resource planning and human resource management. This often requires large investment along with high maintenance costs, even after this these systems become obsolete and require to be updated with further capital investment. This also forces businesses to focus on solving problems which are not related to their core business areas. It is because of these problems that businesses wish to move away from managing large data centers of their own and to migrate these legacy applications and operations to the cloud.

The few migration methods which exist are insufficient to be used for migration of legacy systems to the cloud infrastructure. There is a lack of research proposals in this field which focus on the problems which an organization encounters and needs to resolve while migrating legacy application to the cloud. Some of these factors are (1) Data segregation and security in a multi-tenant environment, (2) Application availability, (3) Application as well as data portability within cloud, (4) Effectiveness of different architectures (functionality and cost).

The goal of this thesis is to develop a cloud migration strategy which shall help an organization to systematically identify the changes which the legacy application requires in its architecture and design before it can be migrated from existing in house IT infrastructure to the cloud. It is to help organizations in planning, decision making and migration of their legacy applications to the cloud.

The thesis presents a migration strategy called **Strategy for Migrating Legacy Applications to Cloud, SoMLAC**. Research made to develop this migration strategy is qualitative and consisted of the development of a preliminary strategy based on interviews, literature study and system observations. The preliminary strategy was later refined with the help of interviews and action research.

The final SoMLAC strategy consists of three migration phases where during the first phase organization migrates its legacy application to the cloud infrastructure, while in the second phase the strategy helps the organization to develop a platform for migration other legacy applications. The third and final phase helps an organization to transform these legacy applications so as to become services which can be used by other organizations. SoMLAC also contains SoMLAC compliance checklist which helps an organization during initial planning and decision making process. The checklist can also be used to validate if a cloud application meets the obligations that an organization has towards maintenance of its customer information.
Here I would like to acknowledge all the people who have provided me with help and support during the course of writing this thesis report.

I am grateful to Visma Consulting AB, for giving me the opportunity to do my thesis at the company and for providing me knowledge, information and resources which were necessary to complete my thesis work. I wish to specifically thank my guide/mentor at Visma Consulting AB, Mrs. Diana Molero, she has been an inspiration and has guided me towards the completion of this thesis.

I am thankful to Prof. Mira Kajko-Mattsson, my examiner at KTH, she has painstakingly taken her time out from a very busy schedule, and has given me feedback and constructive criticism, from time to time.

I wish to thank my wife Vartika and our lovely daughter who motivated me to come back to the university and complete my thesis.

There have been many other people who have helped me during this master thesis, and I wish to thank them all.

Abhinav Mohan

Stockholm, June 22, 2015
Keywords
Cloud Computing, Cold turkey, Chicken Little

Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SoMLAC</td>
<td>Strategy for Migrating Legacy Applications to Cloud</td>
</tr>
<tr>
<td>IT</td>
<td>Information Technology</td>
</tr>
<tr>
<td>IS</td>
<td>Information System</td>
</tr>
<tr>
<td>COTS</td>
<td>Commercial of the shelf</td>
</tr>
<tr>
<td>COTSAM</td>
<td>COTS Anpassnings Metod (COTS customization method)</td>
</tr>
<tr>
<td>IaaS</td>
<td>Infrastructure as a Service</td>
</tr>
<tr>
<td>PaaS</td>
<td>Platform as a service</td>
</tr>
<tr>
<td>SaaS</td>
<td>Software as a service</td>
</tr>
</tbody>
</table>

Terminology

<table>
<thead>
<tr>
<th>Terminology</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Legacy application</td>
<td>Computer program which, although critical to an organization's operations, is in an obsolete format or is installed on an obsolete system. [1]</td>
</tr>
<tr>
<td>Cloud computing</td>
<td>Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction. This cloud model is composed of five essential characteristics, three service models, and four deployment models. [2]</td>
</tr>
</tbody>
</table>
TABLE OF CONTENTS

ABSTRACT ................................................................................................................... i
FOREWORD ................................................................................................................... ii
KEYWORDS, ABBREVIATIONS & TERMINOLOGY .................................................... iii
TABLE OF CONTENTS ................................................................................................. iv
LIST OF FIGURES ........................................................................................................ viii
LIST OF TABLES ........................................................................................................ viii

1 Introduction .............................................................................................................. 1
  1.1 Overview .............................................................................................................. 1
  1.2 Problem ............................................................................................................... 2
  1.3 Goal ....................................................................................................................... 2
  1.4 Contribution ........................................................................................................ 3
  1.5 Delimitations ....................................................................................................... 3
  1.6 Commissioned work ............................................................................................ 3
  1.7 Handling of anonymity ....................................................................................... 4
  1.8 Target audience .................................................................................................. 4
  1.9 Thesis outline ..................................................................................................... 4

2 Research Method ..................................................................................................... 5
  2.1 Research strategy and methodology ................................................................... 5
  2.2 Research phases .................................................................................................. 6
    2.2.1 Pre study and practical study ........................................................................ 6
    2.2.2 Preliminary migration strategy ..................................................................... 7
    2.2.3 Refinement Phase 1 .................................................................................... 7
    2.2.4 Refinement Phase 2 .................................................................................... 7
  2.3 Method ................................................................................................................ 7
  2.4 Research Instruments ......................................................................................... 8
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 Evaluation Model</td>
<td>25</td>
</tr>
<tr>
<td>5.1 Research models</td>
<td>25</td>
</tr>
<tr>
<td>5.2 Investigation criteria</td>
<td>25</td>
</tr>
<tr>
<td>5.2.1 Context</td>
<td>25</td>
</tr>
<tr>
<td>5.2.2 Method</td>
<td>26</td>
</tr>
<tr>
<td>5.2.3 Problem</td>
<td>26</td>
</tr>
<tr>
<td>5.3 The evaluation criteria</td>
<td>26</td>
</tr>
<tr>
<td>6 Strategy for Migrating Legacy Applications to Cloud (SoMLAC)</td>
<td>29</td>
</tr>
<tr>
<td>6.1 Overview</td>
<td>29</td>
</tr>
<tr>
<td>6.2 Phase 1 Move: (Legacy Applications to IAAS)</td>
<td>31</td>
</tr>
<tr>
<td>6.2.1 Steps</td>
<td>31</td>
</tr>
<tr>
<td>6.2.2 Aspects</td>
<td>32</td>
</tr>
<tr>
<td>6.3 Phase 2 Transform: IAAS to PaaS</td>
<td>39</td>
</tr>
<tr>
<td>6.4 Phase 3 Build: PaaS to SaaS</td>
<td>40</td>
</tr>
<tr>
<td>6.5 SoMLAC compliance checklist</td>
<td>40</td>
</tr>
<tr>
<td>7 Model evaluation within the company</td>
<td>43</td>
</tr>
<tr>
<td>7.1 Evaluation overview</td>
<td>43</td>
</tr>
<tr>
<td>7.2 Interviews and surveys</td>
<td>43</td>
</tr>
<tr>
<td>7.2.1 Project 1: Social security system of a large Swedish municipality</td>
<td>43</td>
</tr>
<tr>
<td>7.2.2 Project 2: Pharmacy solution for small and medium businesses</td>
<td>44</td>
</tr>
<tr>
<td>7.2.3 Project 3: Enterprise Content Management (ECM) System for a large Swedish administrative region</td>
<td>45</td>
</tr>
<tr>
<td>7.3 Action research</td>
<td>46</td>
</tr>
<tr>
<td>7.4 Points of change</td>
<td>47</td>
</tr>
<tr>
<td>8 Discussion</td>
<td>49</td>
</tr>
<tr>
<td>8.1 Discussion</td>
<td>49</td>
</tr>
<tr>
<td>8.2 Method results</td>
<td>49</td>
</tr>
<tr>
<td>8.3 SoMLAC at Visma</td>
<td>50</td>
</tr>
<tr>
<td>8.4 Comparison with other research in this area</td>
<td>50</td>
</tr>
<tr>
<td>9 Conclusion</td>
<td>53</td>
</tr>
</tbody>
</table>
9.1 Conclusion ...................................................................................................................... 53

9.2 Recommendations ........................................................................................................ 53

9.3 Future work .................................................................................................................... 53

10 References .................................................................................................................... 55

11 Appendix ....................................................................................................................... 59

11.1 Interview Template 1: “Understanding of company’s processes, project selection and selection of key individuals” ................................................................. 59

11.2 Interview Template 2: “Validation of preliminary strategy against selected company projects” ........................................................................................................... 59

11.3 Interview Template 3: “Validation of the final SoMLAC strategy” ......................... 60

11.4 System observation template ...................................................................................... 60

11.5 Interview transcripts .................................................................................................. 61

11.6 SoMLAC compliance checklist .................................................................................. 61
LIST OF FIGURES

FIGURE 1 ■ RESEARCH STRATEGY .................................................................................. 5
FIGURE 2 ■ RESEARCH PHASES ................................................................................. 6
FIGURE 3 ■ CLOUD MODELS ....................................................................................... 13
FIGURE 4 ■ CLOUD MODELS ....................................................................................... 14
FIGURE 5 ■ TYPES OF CLOUD .................................................................................... 15
FIGURE 6 ■ CHICKEN LITTLE STRATEGY - MIGRATION ARCHITECTURE (REF: DARWIN: ON THE INCREMENTAL MIGRATION OF LEGACY INFORMATION SYSTEMS) ................................................................. 19
FIGURE 7 ■ VISMA CONSULTING’S HISTORY ................................................................. 21
FIGURE 8 ■ VISMA CONSULTING’S ORGANIZATIONAL STRUCTURE .......................... 21
FIGURE 9 ■ RELATIONSHIP BETWEEN RESEARCH CRITERIA AND INTERVIEW QUESTIONS ............................................................................................................ 25
FIGURE 10 ■ OVERVIEW OF SOMLAC MIGRATION STRATEGY .................................. 29
FIGURE 11 ■ SOMLAC LEGACY APPLICATION TO IAAS .............................................. 31
FIGURE 12 ■ TRADITIONAL IT INFRASTRUCTURE ..................................................... 33
FIGURE 13 ■ CLOUD INFRASTRUCTURE ....................................................................... 33
FIGURE 14 ■ THE FLOODED LOBBY AT THE VERIZON SITE AT 140 WEST STREET DURING THE HEIGHT OF THE STORM SURGE MONDAY NIGHT (PHOTO: VERIZON) ................................................................................................. 34
FIGURE 15 ■ THE TRADITIONAL LAYERED APPROACH TO ENTERPRISE SECURITY, FROM COMPUTER FRAUD AND SECURITY (VOLUME 2012, ISSUE 8, AUGUST 2012) .......................................................... 35
FIGURE 16 ■ CLOUD ENCRYPTION SERVICE ............................................................... 36
FIGURE 17 ■ SECURE HYBRID CLOUD .......................................................................... 37
FIGURE 18 ■ PORTABILITY OF VIRTUAL MACHINES BETWEEN DIFFERENT ENVIRONMENTS .................................................................................................................. 38
FIGURE 19 ■ SOMLAC IaaS TO PaaS ............................................................................ 39
FIGURE 20 ■ SOMLAC PaaS TO SaaS ........................................................................ 40
FIGURE 21 ■ VSP AND SOMLAC ................................................................................. 46
FIGURE 22 ■ CHANGES MADE TO THE PRELIMINARY MODEL .................................. 47

LIST OF TABLES

TABLE 1 ■ ILLUSTRATION OF INTERVIEW PHASES AND INTERVIEWED PERSONS .......... 6
TABLE 2 ■ CLOUD FAILURES-2014 ................................................................................ 17
TABLE 3 ■ INTERVIEW 1 (QUESTIONS) .......................................................................... 26
TABLE 4 ■ INTERVIEW 2 (QUESTIONS) .......................................................................... 27
TABLE 5 ■ INTERVIEW 3 (QUESTIONS) .......................................................................... 27
TABLE 6 ■ SOMLAC COMPLIANCE CHECKLIST ............................................................ 41
TABLE 7 ■ INTERVIEW TEMPLATE 1 ............................................................................... 59
TABLE 8 ■ INTERVIEW TEMPLATE 2 ............................................................................... 60
TABLE 9 ■ INTERVIEW TEMPLATE 3 ............................................................................... 60
TABLE 10 ■ SYSTEM OBSERVATION TEMPLATE ............................................................ 61
1 Introduction

1.1 Overview

Take a scenario where one plans to open a simple supermarket store. This seems like a very simple and easy to start business, all one requires is a place to open the store and then buy some products and later sell these to consumers. In practical it is lot more complicated than this. One needs to keep an inventory of stocks along with information of the suppliers and their contract information. The business keeps track of products on the shelf in order to preorder them before they are sold out. By law it is mandatory for the business to keep all financial information updated and pay the taxes where required to do so. Employee information and resource planning tools and processes are required. Businesses have some form of business analysis, such as consumer surveys, in order to understand consumer behavior. These are just a few basic tasks, in reality there are a lot more.

In day to day functioning, the management cannot make decisions without input from the sales and marketing teams. Sales and marketing teams cannot give their input without proper business intelligence tools. Business intelligence tools require that most of the business activity be digitalized, in order to identify patterns which emerge in day to day business functioning. The decisions made by the management need to be then communicated to the people on the floor. Earlier all these tasks were done manually. It was not only inefficient to do these manually but at the same time they were prone to human errors. Thus today businesses use software systems to help with the above mentioned and many other day to day tasks to keep the business functioning such as payroll, financial book keeping etc. This information is critical for the business and thus needs to be protected. This results in a need where businesses need to create a small data center of their own. It is the responsibility of the IT department to provide the business with the necessary software solutions impart training to users and also to maintain these data-centers. An IT department can be from one person strong, to one that employs many hundreds or even thousands of professionals depending upon the complexity and scale of the business. It is ironical that multitude of different software solutions used to fulfill the above mentioned tasks makes it so complex, that at times other IT systems are needed to maintain these IT systems.

Thus, a simple supermarket store which sells vegetables, groceries and other daily needs an army of IT professionals. This has not only increased the cost of doing businesses but has also taken a lot of energy and focus away from core business functions. The basic principle to run any successful business is to keep the costs down and the revenues high and therefore IT departments are often under budgeted and under staffed. A survey of 1,400 CIO’s has identified that 53 percent of IT departments are understaffed [3].

Due to these constraints, often IT departments do not have resources to follow the best practices. Their aim is to simply get the job done at the earliest and make sure that the business IT systems are operational. This approach works in the short term but results in long term maintenance issues which result in cost and time overruns. Unfortunately, there are no simple solutions for this problem.

One solution that IT departments have started to follow is the principle of reusability and using off the shelf software-solution, COTS. Sometimes the off the shelf solution is too generic and needs to be customized to fit the business needs, (COTSAM), e.g. business intelligence reports. Other business functionality which is unique to the business needs to be developed in-house. All software components require three things (1) place to run, (2) people to maintain, and (3) training and knowledge on how to use these.

For a modern business function it is unthinkable that the IT systems are unavailable for extended periods of time. An average American retail company makes 18-20% of its yearly sales during the holiday season [4]. Any system malfunction during such critical periods can be catastrophic for the business. Thus the businesses often build multiple layers of redundancy. Needless to say that
all these resources have to be maintained and upgraded during their lifetime. All of this increases human capital and financial costs for the business.

The businesses have now begun to question and ask for a solution to this ever increasing complexity of their IT-infrastructural resources where they cannot function without the IT systems but at the same time do not have resources, financial capacity, technical knowledge or motivation of having dedicated data-center of their own. This critical business need has been identified by many different IT companies as an opportunity. The researchers and companies such as Amazon™, Microsoft™, and RackSpace™ have analyzed this core business requirement and have recommended cloud computing infrastructure and services as a possible solution. Here, cloud service provider companies are creating massive centralized data centers across the world and hiring out parts of it to other businesses.

This reduces the burden on the local IT departments for maintaining the data-centers themselves and they can begin to focus on the functional aspects for the business providing more value to the business. This model even allows the IT departments to be more responsive to the changing business requirements, for example, traditionally an IT department needs to heavily invest in the data-centers to meet the requirements during the peak in business activity, such as holiday season. This extra capacity is often underutilized during the lean periods. But, by hiring the computational capacity from external vendors the local IT can scale up and scale down, without effecting the normal business functions. Thus the business only pays for the computational resources while they are utilized and not while they are idle.

It has taken many years for businesses to build and customize their IT systems for their specific needs. At the same time businesses realize that they need to keep these systems updated to meet new and changing business requirement. While doing so the businesses wish to reduce the costs that these future upgrades will require without compromising on the business continuity.

Companies such as Visma Consulting have often experienced that the customers are reluctant to migrate to the cloud. The cloud is new and the businesses wish to know more about the different approaches they can take if they choose to migrate their existing legacy systems from local infrastructure to the cloud. They need answers to commonly raised concerns relating to the shared nature of the cloud infrastructure. They need answers to the issues being raised in newspapers and journals, relating to outages and security breaches of cloud infrastructure. There are still lack of standards relating to cloud infrastructure and this raises concerns related to future proofing their investment. Overall the businesses need a clear vision for the future.

Even though there are some traditional migration models which help in migration of legacy applications, these traditional migration models do not deal with the complications and complexities faced when migrating legacy applications to the cloud. This thesis aim to address this issue.

1.2 Problem

The few migration methods which exist are insufficient to be used for migration of legacy systems to the cloud infrastructure. There is a lack of research proposals in this field which focus on the problems which an organization encounters and needs to resolve while migrating legacy application to the cloud.

1.3 Goal

The goal of this thesis is to develop a cloud migration strategy which shall help an organization to systematically identify the changes which the legacy application requires in its architecture and design before it can be migrated from existing in house IT infrastructure to the cloud. It should help organizations in planning, decision making and migration of their legacy applications to the cloud.
The strategy shall be qualitative in nature in order to give it flexibility and make it useful not only for “Visma Consulting AB” (organization where the thesis is being conducted) but for any other organizations which wishes to migrate their legacy applications to the cloud. The strategy has a short term goal and a long term goal. The short term goal is to help organizations during the decision making process, where the organizations need to consider different aspects related to cloud environment. The long term goal is to help organizations during the phase when the legacy application is actually being migrated to the cloud.

Over the years the organizations have made large investments in their IT systems and infrastructure. These systems are critical for normal day to day operations. Upgrading and migrating any system is a costly and time consuming process with many risks involved. Therefore it is necessary that the migration to the cloud be done with minimum disruptions to normal business functions. The process should not require exceptional startup investment and should not require rebuilding of systems as these have been customized specifically to the organization’s needs. It has taken organizations many years with a lot of investment in terms of human and capital resources.

1.4 Contribution

This thesis study has proposed a generalized migration strategy for migration of legacy applications to the cloud, this cloud migration strategy can be used with other standard application migration strategies such as Chicken Little or Cold Turkey. The migration strategy is called SoMLAC (Strategy for Migrating Legacy Applications to Cloud). It is a set of checklists which an organization should consider while decisions are being made and the actual migration is being undertaken.

SoMLAC has been implemented as part of action research. SoMLAC strategy has also been evaluated against various different ongoing as well as previously completed projects at Visma Consulting. SoMLAC is generic and it does not limit itself to a specific application or organization.

1.5 Delimitations

The thesis is an industry thesis being conducted at a company called Visma Consulting AB. Thesis is restricted to analysis of different cloud strategies. Driven by the time constraint along with unavailability of the projects, the thesis work has focused more on Phase 1 (Moving a legacy application to IAAS) of the SoMLAC strategy.

Often each individual commercial cloud vendor has its own tools and command languages to communicate with their cloud infrastructure, in order to setup cloud environments and also to do routine tasks such as machine startup, machine shutdown, configure gateway accesses etc. Thus the thesis does not aim to act as a “how to” guide for setting up cloud infrastructure but is aimed at being a “what to” guide which answers what is needed to be considered and done when migrating applications and infrastructures to the cloud.

As the cost of cloud infrastructure is vendor specific and is also negotiable, the thesis therefore does not aim to focus much on cost aspect and will only look at it from an objective point of view. The thesis aims to delve more into other aspects of cloud paradigm such as security, availability and portability.

1.6 Commissioned work

Visma Consulting has given the assignment to develop a strategy which will not only help the organization during decision making process for applications that need to be migrated to the cloud but also help the organization when these projects are being executed. The assignment included study of literature in the problem domain along with collection of knowledge which the company has from previously executed projects. The proposed strategy was to be tested on one project called
VSP which the company is responsible for. This has formed the basis for SoMLAC (Strategy for Migrating Legacy Applications to Cloud).

1.7 Handling of anonymity

Visma Consulting required that the anonymity of its employees and customers be maintained. Therefore during the interviews and the writing of this thesis, anonymity of the company project, employee and customer has been maintained. This has helped in providing an open platform to the people involved and provide an unbiased feedback, which has helped in improving the quality of this thesis.

1.8 Target audience

The user group for the thesis are the corporates, researchers and analysts who are working in the field and helping organizations migrate their legacy applications as well defining long term cloud migration strategies for organizations.

Senior management can use this thesis while decisions are being made to migrate legacy applications to the cloud as the thesis helps them identify the risks involved as well provides a checklist of questions which the management should answer before undertaking the project. The sales team can use this thesis when doing the cost estimates along with when defining the SLA agreements. The project management teams can use this thesis to identify the challenges, risks and complexities which they can expect to encounter during the execution of the project, helping them in project planning and execution.

1.9 Thesis outline

The thesis consists of following chapters:

- **Chapter 1**: This chapter introduces the problem, goal, contributions, delimitation, involved parties, target audience and disposition.
- **Chapter 2**: This chapter describes the research method. What type of research has been conducted, selection of the research strategy, research steps and the instruments utilized. Finally it handles the validation challenges that the results can suffer and their handling.
- **Chapter 3**: This chapter gives an extended background to cloud computing and the existing application migration strategies.
- **Chapter 4**: Provides company description for Visma Consulting.
- **Chapter 5**: This chapter presents the evaluation model for SoMLAC
- **Chapter 6**: This chapter presents SoMLAC migration strategy as well as the modifications made to the preliminary model after the model was validated against different projects.
- **Chapter 7**: This chapter presents how the SoMLAC was validated against different company projects, with the help of interviews, action response. The chapter concludes by comparing the SoMLAC to the existing work in the field.
- **Chapter 8**: This chapter discusses how the problem has been solved, how it compares to similar research in the area and the challenges faced during the thesis work.
- **Chapter 9**: This chapter contains the conclusion and proposal for the future work.
- **Chapter 10**: This chapter contains the appendixes which contain the template for the questions used for the interviews as well as the template used for the system observation.
- **Chapter 11**: This chapter contains the references used during the course of this thesis.
This chapter provides information about the research methodology used during this thesis work. Chapter 2.1 defines the research strategy and methodology. Chapter 2.2 describes the five research phases. Chapter 2.3 describes the method and Chapter 2.4 describes the research instruments used. Chapter 2.5 deals with the ethics. Chapter 2.6 lists the validation risks for this thesis and their handling. Chapter 2.7 describes the experience gained during this thesis work.

2.1 Research strategy and methodology

Problem area which is under consideration is vast and extremely complex. It not only requires understanding of how the cloud infrastructure works and the complexities which a legacy application faces during migration but it also requires an understanding of the organizations internal processes and methodologies. In this thesis this knowledge has been mapped to the literature on this topic.

Figure 1 provides an overview of the research strategy utilized during this thesis. The research strategy consisted of research methods, research phases, research instruments, selection of respondents and managing of validation threats.

The research method selected for this thesis is qualitative. The five research phases form the research process that have been conducted during this thesis. The research instruments used during the thesis have been interviews, observations and literature study. The interviews have been the main source of input as during that the respondents provided information from their past experiences. The respondents were chosen based on convenience sampling as well as selection criteria. Selection criteria for contributors has been that they have either previously worked with a project that has been migrated to the cloud or there is an intent to migrate their system to the cloud in a foreseeable future. Finally the validation threats were identified which can often compromise the results of a qualitative thesis.

Figure 1 ■ Research Strategy
2.2 Research phases

Thesis consisted of 5 research phases, which have been shown in the Figure 2

1. Pre-Study consisted of literature study and understanding the state of practice study
2. Practical study consisted of selection of candidate projects and key persons along with system observation
3. Creation of a preliminary migration strategy
4. Refinement Phase 1 of the preliminary migration strategy with the help of interviews
5. Refinement Phase 2 of the preliminary migration strategy with the help of action research and interviews.

Section 2.2.1 describes the first two steps which cover literature study and selection of candidate projects along with identification of key people. These activities were conducted in parallel as to understand company processes it was necessary to also observe company projects as well as interact with key individuals. Section 2.2.2 describes the process for creation of preliminary migration strategy. This is followed by Section 2.2.3 which describes how the preliminary model was refined and evaluated. The final Section 2.2.4 describes how the final migration strategy was verified with the help of action research.

![Figure 2 - Research Phases](image)

### 2.2.1 Pre study and practical study

Although literature study was conducted during the whole course of this thesis, it can be grouped into two phases. In the first phase an intensive literature study was to understand the problem area. Later during the course of thesis work this understanding was updated with more literature study. Under literature study many different sources were utilized such as books, journals, research papers, web, corporate sites as well as other related thesis works covering cloud computing as well as legacy system migration web articles, along with white papers published by different industry leading companies such as IBM, CISCO, Microsoft, Amazon, RackSpace.

<table>
<thead>
<tr>
<th>Interview Person</th>
<th>Interview 1 using Interview Template 1</th>
<th>Interview 2 using Interview Template 2</th>
<th>Interview 3 using Interview Template 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interview Person 1</td>
<td>x</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Interview Person 2</td>
<td>x</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Interview Person 3</td>
<td>x</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Interview Person 4</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interview Person 5</td>
<td>x</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Interview Person 6</td>
<td>x</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Interview Person 7</td>
<td>x</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1 shows all the interviews which were conducted during the course of this thesis. During Pre study and practical study phase Interview 1 was conducted. The template used for Interview 1 is included inside Section 11.1 Interview Template 1: “Understanding of company’s processes, project selection and selection of key individuals” (Appendix).
Using information collected during the interviews a number of company projects were selected. These were then observed with the help of the observation template which also is included inside Section 11.4 System observation template (Appendix). During observations the selected systems were presented and system functionality and architecture were demoed. As systems observed are proprietary of Visma Consulting’s customers the observations of system functionality, architecture as well as interviews have not been recorded and made available as part of this thesis.

2.2.2 Preliminary migration strategy

During this step a preliminary migration strategy was developed. This preliminary migration strategy was developed as a result of interviews, system observations and literature study conducted under the first two phases of the research process. Research techniques used for development of the preliminary migration strategy have been the migration strategies proposed by Brodie et al., they have proposed two approaches namely Cold Turkey and Chicken Little [5], along with the migration guidelines as proposed by Bergey et al. in their report DoD Legacy System Migration Guidelines [6].

Figure 10 Overview of SoMLAC migration strategy, in Section 5.1, shows the preliminary migration strategy which has been developed during this step. Strategy is iterative in nature, thus providing the company and projects flexibility while the applications are being migrated. At the same time it also helps various departments inside the organization to iteratively develop competence for developing and maintaining more and more complex cloud solutions and infrastructures.

2.2.3 Refinement Phase 1

A preliminary migration strategy was then developed using input from Visma Consulting and literature study. The system observations and interviews conducted in Phase 1 were input from Visma Consulting, where application risk factors and the organizational factors (such as budget, schedule and resources availability) which may affect migration strategy were considered. The literature study was used to define in detail the different legacy system migration aspects such as; user identification and access control (IAM), secure data storage.

Once the preliminary migration strategy SoMLAC was developed the refinement phase 1 was conducted at Visma Consulting with the help of Interview 2, the template used for this interview is included inside Section 11.2 Interview Template 2: “Validation of preliminary strategy against selected company projects” (Appendix). The aim of this interview was to ask the respondents give feedback about the validity of the preliminary model with respect to the project they are currently working in or have worked with in the past. During these interviews it was found that although the model was found to be effective and reusable in many projects, there were some scenarios were it did not work. The problem identified was how to follow the model even though the legacy system being migrated required many complex changes to its architecture and design before becoming compatible for cloud migration. This decision making process needed to be addressed in the preliminary migration strategy.

2.2.4 Refinement Phase 2

With inputs from verification of preliminary migration strategy (SoMLAC) the final migration strategy was developed using action research. The details of the project used for action research are provided under Section 4.3.4 Action research project: VSP, Errand Management System for the Swedish counties. The resulting strategy was then verified using interview 3, the template used for the interview is present in Section 11.3.

2.3 Method

The thesis focused on an area which is very new although migration of legacy systems is a well-documented and understood process but how these standard migration processes needs to be
transformed with respect to cloud computing is little understood. The literature is fragmented where articles and journals often focus on individual problem areas and do not give a complete picture. Along with problem with lack of comprehensive literature there are not many real world examples which can be used. Even the organization where this thesis has been conducted had a limited number of projects which could fulfill the criteria for this thesis. As the organization is a consulting organization the application code as well as documentation is the proprietary to the end customer, and thus no direct references could be made to these.

Thus the qualitative research was selected to manage the above mentioned difficulties. A number of case studies of organization’s previously completed projects were conducted to gain deep understanding of the problem area and the complexities involved. The case studies consisted of interviews as well as observations. Inductive reasoning along with hermeneutics were employed to develop a preliminary model and its validity was tested using action research. The action research was conducted on a project which was being executed at Visma Consulting during the time of this thesis.

It was not possible to conduct quantitative research for the purpose of this thesis, as it deals with a vast problem area which does not restrict itself to a specific domain. As a legacy application can be any application developed in any programming language using a multitude of architectural principles.

As this thesis is qualitative in nature, it is susceptible to different interpretations. Therefore the thesis has referenced the relevant literature as well as tried its best to define the context in which the deductions have been made. Thesis defines a generalized workflow which an organization needs to follow for migrating legacy applications to the cloud. During the workflow thesis helps to identify questions such as when and what needs to be done or considered rather than who will do it and how it will be realized. During this thesis it was found that although When and what are questions which are generic and needs to be done irrespective of organization or project, who and how are project and customer specific and are not the same. It is therefore that they have been kept out of the context of this thesis.

2.4 Research Instruments

The research instruments which were employed used during this thesis included interviews, observations, action research and literature study.

The interviews were structured and complemented with observations. Action research was used to refine the strategy and test it in a real world situation. To get a comprehensive and diverse view, various different people from across different domains of the company were interviewed. The people included those who have previously worked in projects in which cloud infrastructure has been utilized as well as projects where new cloud solution have previously been developed. They included department chiefs, sales representatives, business consultants, project managers, architects, developers and maintenance managers.

2.4.1 Alternative investigation strategies and methods

Apart from regular structured interviews, corridor and coffee time discussions have been conducted to get feedback from as many different people as possible, some of which have been very informative and have helped immensely. Action research for the customizing of the preliminary model has also been an alternative investigation strategy.

2.5 Ethics

Four ethical principles followed during this thesis were (1) Information requirement, (2) Consent, (3) Confidentiality and (4) Intellectual property rights.
Information requirement: this requires that the respondents be aware of the context in which the information they are sharing shall be used. This was fulfilled as the employees at Visma Consulting were informed about the thesis work being conducted. As well as respondents were also informed about the thesis work being conducted, its aim and scope.

Consent: this requires that the respondents give their consent before the information shared by them is utilized. The company gave consent that the information shared by its employees can be used for the thesis work. Apart from this during discussions the respondent were informed that the information they share may be used for the thesis work and if they do not wish their information to be used they can inform about it.

Confidentiality: it deals with the fact that requirement for anonymity has been fulfilled. Visma consulting requested that the names as well as details of its clients, projects and employees not be used during the writing of this thesis. Therefore this thesis does not use any of these and the requirement has been fulfilled.

Intellectual property rights: it requires that the information used from different sources be clearly referenced. The thesis tries its best to give due credit to all those who have given their valuable input along with sources for the literature study as well as references.

2.6 Validation

Qualitative research is judged by four criteria [7]: (1) Credibility, (2) Dependability, (3) Transferability and (4) Conformability.

Credibility: deals with justifying the credibility of the research results. The credibility of this thesis has been verified using the interviews that have been conducted during the course of this thesis as well as the verification and customization of the preliminary model using action research.

Dependability: it aims to evaluate the research process as repeatable and stable over time. The research was conducted inside the organizations with organizations projects and employees as respondents. Thus it requires that more similar migration strategy alternatives be developed in other organizations and the results of this thesis be verified against those.

Transferability: it deals with answering how much the thesis can be generalized. The fact that this is an industrial thesis being conducted at Visma Consulting, it is possible that the organizational factors at Visma Consulting have influenced the results of this thesis, but the thesis has tried its best not to tie itself to the Visma Consulting’s project management model and keep it independent for the sole purpose of being reusable for any other organization which wishes to do so.

Conformability: this aims that the results of the thesis not be biased. This threat was corrected using a number of different projects and people from different domains. The results have been also tested using action-research.

2.7 Experience

Thesis has provided me experience and understanding of the complexities faced in an organization. A solution is successful not only because of the technology used but because of the entire ecosystem around it. Any fundamental change such as migrating to the cloud has a domino effect across the organizational structure, from contractual obligations, project planning, resource planning, development planning and maintenance; each is represented by its own organizational entity such as sales organization, development organization and maintenance organization.
3 Background

This chapter provides the background. Where Chapter 3.1 gives an introduction to cloud computing. Chapter 3.2 describes the different cloud characteristics such as on-demand self-service, broad network access, resource pooling, rapid elasticity and concept of measured service. Chapter 3.3 describes the different cloud models IaaS, PaaS and SaaS. Chapter 3.4 introduces public, private and hybrid cloud. Chapter 3.5 presents problems related to accountability and responsibility. Chapter 3.6 describes cloud security. Chapter 3.7 describes maturity of cloud services and cloud concerns. Chapter 3.8 describes the existing application migration methodology. Chapter 3.8.1 describes Cold turkey/big bang migration strategy. Chapter 3.8.2 describes the Chicken Little/Smooth migration strategy. Chapter 3.8.3 describes the commonalities between these strategies. Chapter 3.8.4 provides evolutionary requirements to these existing migration strategies for cloud migration.

“Computing is much the same as it was 40 years ago. It’s a huge amount faster, more energy efficient and a lot smaller, but the general principles are still there.” Kevin Murrell [8]

Although it is unclear who coined the term Cloud computing but the concept itself was introduced as early as in 1950’s with the introduction of mainframe computers where the centralized computing resources were accessed via thin clients/terminals. The centralized resource in form of mainframe computers was expensive and limited. Resource allocation of these computing power houses was a challenge, David Hartle, a former director of the Cambridge University Computing Service and adviser for the British prime minister’s office, experienced it firsthand while managing the university mainframe. He was a witness to arguments between people fighting to get access to this limited resource, which affected not only the social interactions but also limited creative freedom.

With the introduction of the first Apple computer in 1976 and of IBM personal computer (PC) in 1981, although these were not as powerful as mainframes but they belonged to individuals, this was the solution for the limited resources offered by the mainframes and gave unlimited freedom to the users, who no longer needed to wait in long queues.

These had a significant negative impact on centralized computing which became limited to very large scientific computing application such as super computers. At the same time PC gave a tremendous boost to the computing industry and made it possible to digitalize many different aspects of life for example digital communication, electronically submitting and following up on applications, e-commerce etc.

According to Gartner, in just 2013 over 2.3 billion digital devices were shipped [9]. This explosion of IT adoption in daily lives has made the users more knowledgeable in its use. Users demand new and more advance functionality at a pace which is a challenge for even the major IT powerhouses to keep pace with.

Traditionally the software has been provided as packages which required to be installed on devices. This was manageable until there were a limited number of device platforms. But with the introduction of smart devices the ecosystem has been flooded with a variety of different device configurations. It is not possible for any solution provider to keep pace with this ever changing scenario and they have been looking for a more effective way of taking their software and services to the end consumer. At the same time large organizations need more effective IT management strategies for the users, as the limited resources which they have find it challenging to support all the users and the users have started to feel the same frustrations which the users of mainframe computers used to feel before the introduction of IBM, PC.

With the rapid increase in computing capacity and the decrease in cost of hardware, it has again become possible to move back to the centralized computing environment without compromising
user freedom and creativity thus allowing the users to focus on the utilization of the technological resources rather than maintaining it.

In 2008 Eucalyptus was the first open source, Amazon web service compatible platform, which brought the centralized computing again into the forefront. Since then many other businesses have introduced cloud service; some of the significant players are AWS™, Rackspace®, and Azure™. This seems to offer a win-win situation to both the consumers and the service/solution providers. The consumers need not update their devices constantly while the service/solution providers can directly provide their offering to end consumer with ease of centralized hosting.

What the cloud solution providers aim to provide is a means where businesses can reduce these overhead IT costs. This can be achieved in three ways

- Moving the IT infrastructure to standardized data centers.
- Using standard platform features inside the data centers to develop custom business applications.
- Using off the shelf cloud applications as a service.

3.1 Introduction to cloud computing

If I wish to charge this computer or watch television, I do not need to have a personal power plant of my own. I simply need a power outlet to which I can plug my device. Based on the amount of electricity I have consumed I pay the bill to the electricity company. These kinds of services such as electricity, water, sewage etc. are generally termed as utility services. Cloud computing aims to take this concept of utility service to the domain of computing facilities. Thereby doing away with the need of having dedicated data-centers. In doing so, one can reap the benefits of economics of scale, where the costs are shared and the quality is improved, in form of constant optimization and research in these shared data centers.

Cloud computing has been defined by NIST [2] as a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction.

3.2 Cloud characteristics

3.2.1 On-Demand Self Service

This allows the cloud users to provision applications themselves without requiring direct help from the IT department or from the cloud service provider. This is often achieved with the help of predefined templates, which are developed and provided by the cloud service provider or the local IT organization and are often available through a portal. End users based on their account profile or level of access can use these templates.

3.2.2 Broad Network Access

This implies that the cloud applications and resources are available over the network and can be accessed through different device types (PC, tablets, smartphones etc.).

3.2.3 Resource pooling

Cloud resources are designed to be generic and can be shared between applications and clients. This allows for the optimal utilization of resources. The cloud resources which are pooled can be located at different data-centers’ which might be in the same location or can be geographically distributed.
3.2.4 Rapid elasticity

Cloud offers elastic provisioning of resources, which enables the application providers to increase and decrease the cloud infrastructure capacity as and when needed. Thus the applications providers pay for the resources as and when they are required and do not need to have over capacitated datacenters.

Traditionally, the SLA (Service Level Agreements) required the application service providers to invest heavily in their infrastructure. Many of the business functions are cyclic in nature, for example, the online sales are much higher during holiday season compared to the average sales during rest of the year. Also, at times the popularity of the service being offered can vary because of the market dynamics; it may as well be much below the expected market popularity while the service was launched. This often resulted in underutilized datacenters. This problem can be avoided by using cloud infrastructure with the help of rapid elasticity.

3.2.5 Measured Service

Services and applications which are deployed in the cloud can be monitored and measured. This information is used when decisions need to be made about the increase or decrease of resources for the services and applications hosted in the cloud. This information is also used for billing purposes.

3.3 Different cloud models

Cloud computing has evolved over the years and is no longer restricted to providing only the computing resources such as virtual machines running in remote data-centers. Cloud services are classified into three major categories. (1) Infrastructure as a Service (IaaS) (2) Platform as a Service (PaaS) and (3) Software as a Service (SaaS). These three categories are corresponding to three basic demands that the IT departments/businesses have, (1) to be able to host service developed in house or sourced, (2) to be able to build solutions employing off the shelf functionalities, (3) to be able to use readymade solutions. These cloud models are often called XaaS. Where X can be anything that is used or provided as a Service. Example of others not so common cloud services are SECaaS (Security as a Service), DbaaS (Database as a Service).

The three models are dependent on one another as IaaS forms the backbone which provides the real computing power, on top of this we have the PaaS which consists of services which can be used when creating cloud applications. On top of PaaS we have the final layer consisting of SaaS, these are the applications created by software vendors which can be directly consumed by the end users. This has been depicted in the image below.

![Figure 3 ■ Cloud models](image)

3.3.1 Infrastructure as a service (IAAS)

Infrastructure as a service is where a company creates a data center and provides this for hire to other companies for a fee. The companies that hire the datacenter from another are freed from
hassles of maintaining it themselves as well as they do not need to hire the complete data-center, they can hire only a part of it to meet their business needs. At the same time as these on hire datacenters are elastic in nature the companies can very easily ramp up and ramp down their hired computing capacity based on the changing business environment. The aim of IaaS is to provide computing infrastructure as a service just like any other utility, such as, water, electricity or water, where the consumer pays as per the amount of usage rather than a large one time investment along with high maintenance costs.

As a result the companies can drastically reduce their commitment to the overhead costs of maintaining local in-house IT services. Thus eliminating the need of hiring and maintaining a large team of IT professionals and only a small agile team is sufficient to manage the cloud infrastructure.

Apart from the cost advantage the companies gain on the quality of the computing infrastructure. As these infrastructure providers are experts in their areas and they build the infrastructure solutions based on the best practices, something which often was out of the reach of the local IT departments of small and medium scale businesses.

### 3.3.2 Platform as a Service (PaaS)

PaaS is used while developing solutions/applications for the cloud infrastructure. The concept of PaaS closely resembles the traditional SOA architecture where different standard pre-fabricated services are used when developing the applications. The difference being that these services are developed to be even more generalized so that they can be used in many different applications which may even belong to different organizations.

An example of such PaaS is Microsoft® Azure™ which offers a platform for hosting of web-applications as well as storage of web application data. Azure also offers the possibility to integrate the web-application with other services, applications and devices using the Azure™ service bus [10]. This can be achieved without having to manually create and configure virtual machine instances.

### 3.3.3 Software as a Service (SaaS)

SaaS solutions, where a software is provided as a service has been one of the major success stories where corporates such as Adobe have started providing their end solutions as a service; which can be bought and used on pay-as-you-use model. This form of software delivery has been extremely popular as it does away with the end user’s hassles of installation, activation and upgrade of software. Even for the software provider, it has reduced the cost of development, support and maintenance as most cloud based SaaS solutions are web based and all that is required from end user is access to a modern web browser. During development of the software, one does not need
to take into consideration the traditional questions such as for which operating system is the application being developed, which often required that the same software had to be developed in multiple programming languages which are optimized for the given platform such as Objective C for OSX and .Net for windows while C/C++ for Linux. Thus not only does this reduce the software development cost but it also reduces support and maintenance costs. As the software manufacturers have to now focus on only one code base thus this model has the potential to provide much more stable and reliable product to the end customers, perhaps with even more features.

**Figure 5 ■ Types of cloud**

### 3.4 Types of cloud (Public, private, community or hybrid)

At the core, cloud is simply a large collection of undedicated computing resources, which are available for consumption by applications and systems that require it. This basic nature of the cloud does in no way directly imply that cloud has to be outsourced. Very large corporations which have enormous data-centers can themselves create cloud computing infrastructure. Theoretically, even a group of individuals can share their computing resources into a common pool and use it as a cloud infrastructure.

There are many arguments as to why large corporations and group of individuals would like to create their own cloud infrastructure. In case of large corporations the motivation can be decoupling of computing resources from the applications, for example: a corporation having two data-centers, one in United Sates and the other one in China, can use the idle capacity of its Chinese data-center during the holiday season when it has large number of customer transactions in United States. Also the same is possible during the Chinese New year, where the excess US data-center capacity can be utilized. This is only possible if the US data-center and the Chinese data-center are not individual dedicated computing resources for the respective markets. They need to be a single entity. Such cloud infrastructures hosted by companies for their internal use are called Private Cloud. An example of private cloud is the CERN OpenStack Cloud [11], it is expected to reach 150,000 cores by 2015 making it the largest scientific cloud infrastructure in the world [12].

Similar is the argument for a cloud infrastructure shared between individuals. These individuals can be researchers working in different organizations and on different research topics. As the research funding’s often are limited and researchers often face the problem that the local IT departments are slow in providing the necessary computing resources for their research. Researchers might decide to create a shared pool of resources between themselves and use this as an elastic cloud infrastructure. Such clouds are termed as Community cloud.

Another example of community cloud infrastructure is where some businesses which have private cloud would link their cloud infrastructure with their partner companies cloud infrastructure. This is not unthinkable as even today companies often have their IT systems linked with another companies IT infrastructure through techniques such as DMZ, firewall and secure VPN access.

The last and the most recognizable form about type of cloud is the Public cloud. This is the commercial cloud infrastructure which is provided by the cloud service provider for hire to its customers.
At times it may make sense to use a combination of above cloud types, for example because of the nature of the information it might be necessary to save this information in private infrastructure while other parts of the application might be hosted in the public cloud, thus resulting in a hybrid cloud infrastructure. A researcher working in a large university might be using the local cloud infrastructure of the university in combination with the resources available in the community cloud infrastructure, thus creating a hybrid cloud of their own.

3.5 Cloud accountability and responsibility

Analogy for the accountability and responsibility of cloud infrastructure can be made with the consumption of electricity by a consumer. I being a consumer can control if I wish to switch on the light in the room or not, but it is the responsibility of the electricity company to make sure that the electricity is being generated at a remote location and transported to my home, so that when I choose to turn on the light switch the bulb will glow. Similarly the responsibility that infrastructure in the cloud is working lies with the cloud service provider; while in a traditional data-center, it is the local IT-department which is accountable and responsible.

This raises the question of accountability and responsibility from end user perspective. The local IT-departments are accountable to the business and the end users, but it is the cloud service provider which is responsible for the infrastructural resources. This can lead to situations where the local IT-departments have found themselves helpless in the absence of clearly defined SLA agreements with the cloud service providers. Problem has been taken up by many research groups and one of these Cloud Computing Use Case Discussion Group has defined in their white paper Cloud Computing Use Cases White Paper version 4.0 the different aspects which should be considered while an SLA agreement is being formalized between the service provider and the consumer [13].

3.6 Cloud security

Cloud infrastructure is shared; it is not unimaginable that the same hosting environment is used by competing businesses. Thus taking time and understanding how the cloud resources are utilized and the security of information stored in it is critical for any business which is using or plans to use cloud resources.

It is the responsibility of the business that is using cloud infrastructure, to guarantee that the privacy and legal requirements related to personal information of their users are being fulfilled. Diogo et.al. [14] Have identified in a cloud security survey that the characteristics of the cloud environment are well understood from business aspects but there is still no clear understanding and comprehension about the security aspects related to information and data stored in the cloud. The issues range from the data which is being stored and accessed from the cloud infrastructure, to the people who are managing the cloud infrastructure itself as well as impersonation and identity theft of authorized users.

These security issues have raised questions on cloud computing itself and security experts such as John Viega [15], argue that it is too risky to move infrastructure to the cloud and that major players might even choose to shy away from the cloud. Their view is that cloud requires third party certifications and standardization before it is acceptable to larger audiences.

3.7 Maturity of cloud service infrastructure and cloud concern

With the popularity of the cloud service model, a number of initiatives have been taken to standardize the creation and management of cloud resources. One such prominent community driven initiative initialized by NASA and Rackspace is OpenStack [16], an open source cloud operating system which can be used for creating public as well as private clouds.
In October 2012, hurricane Sandy racked havoc to many data-centers in and around New York [17]. To overcome such situations, today the cloud service providers have data-centers spread across geographic locations for redundancy.

With the ever growing number of cloud service providers, where some cloud service providers have competitive pricing model while the others provide more stability as well as cloud platform features; it raises the question of portability, which deals with enabling the cloud service or application to be moved from one cloud provider to another. Due to the lack of standards it is often not possible to do this and should be considered when a cloud service provider is being selected, as this decision can have long lasting effects on the cost and risk analysis.

Traditional applications can often not be directly migrated to the cloud as cloud is a shared environment while the original applications were often developed with the understanding that they will be used in dedicated and isolated environments. This requires changes to the basic application architecture before an application can be migrated to the cloud.

While having the systems in-house, businesses have a feeling of security where they are in control of their information and resources. When the question is raised to move these critical resources into centralized locations or in the hands of another company, it often raises eyebrows and is followed by skepticism. One reason being, recent events reported in media as well as lack of success stories where businesses have successfully moved to the cloud.

Cloud Computing Vulnerability Incidents [18] report has identified that between 2009 and 2011 the number of cloud incidents have raised from 33 to 71. It mentions that one of a possible reason for this is the rapid growth in the number of cloud service during this period. The following year “Cloud Computing Vulnerability Incidents report published by Cloud Security Alliance in 2012” and later revised in March 2013 reported that 172 incidents were reported till 2011. Of these 172 incidents only 129 have declared the cause while the others remain unknown. The top 3 cloud providers namely Amazon, Microsoft and Google accounted for 56% of all non-transparent incidents.

To understand the challenges faced by Cloud services we can take a glimpse at the most widely reported cloud outages during 2014 [19, 20]. Apart from this, there are many other issues which have occurred. This raises many issues related to security, stability and availability of cloud resources which need to be considered while migrating applications to the cloud.

<table>
<thead>
<tr>
<th>Date</th>
<th>Cloud Service</th>
<th>Vendor/Product</th>
<th>Duration</th>
<th>Cause</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014-01-06</td>
<td>IaaS</td>
<td>Amazon - AWS</td>
<td>24 hours</td>
<td>Fiber line cut [21]</td>
</tr>
<tr>
<td>2014-01-10</td>
<td>SaaS</td>
<td>Dropbox</td>
<td>2 days</td>
<td>Error during routine maintenance</td>
</tr>
<tr>
<td>2014-01-24</td>
<td>SaaS</td>
<td>Gmail, Google calendar, Google Docs and Google+</td>
<td>Few hours</td>
<td>Software bug</td>
</tr>
<tr>
<td>2014-03-14</td>
<td>SaaS</td>
<td>Dropbox</td>
<td>1 hour</td>
<td>Service</td>
</tr>
<tr>
<td>2014-03-17</td>
<td>SaaS</td>
<td>Google</td>
<td>3.5 hours</td>
<td>Maintenance issue: routine procedures redirected traffic to the wrong set of server</td>
</tr>
<tr>
<td>2014-03-24</td>
<td>SaaS</td>
<td>BaseCamp</td>
<td>2 hours</td>
<td>DDoS (distributed denial-of-service) attack</td>
</tr>
<tr>
<td>Date</td>
<td>Service Type</td>
<td>Platform/Service</td>
<td>Duration</td>
<td>Description</td>
</tr>
<tr>
<td>------------</td>
<td>--------------</td>
<td>-----------------------------------</td>
<td>------------</td>
<td>--------------------------------------------------</td>
</tr>
<tr>
<td>2014-04-20</td>
<td>PaaS</td>
<td>Samsung Smart TV platform</td>
<td>4.5 hours</td>
<td>Fire in data-center</td>
</tr>
<tr>
<td>2014-05-16</td>
<td>SaaS</td>
<td>Adobe – Creative Cloud</td>
<td>28 hours</td>
<td>database maintenance activity</td>
</tr>
<tr>
<td>2014-06-10</td>
<td>SaaS</td>
<td>Evernote</td>
<td>10+ hours</td>
<td>DDoS (distributed denial-of-service) attack</td>
</tr>
<tr>
<td>2014-06-11</td>
<td>SaaS</td>
<td>Feedly</td>
<td>3 days</td>
<td>DDoS (distributed denial-of-service) attack</td>
</tr>
<tr>
<td>2014-06-12</td>
<td>SaaS</td>
<td>Apple - iCloud</td>
<td>Few hours</td>
<td>Unknown</td>
</tr>
<tr>
<td>2014-06-23</td>
<td>SaaS</td>
<td>Microsoft – Lync</td>
<td>Several</td>
<td>network routing infrastructure issues</td>
</tr>
<tr>
<td>2014-06-24</td>
<td>SaaS</td>
<td>Microsoft – Exchange online</td>
<td>9 hours</td>
<td>Portion of [its] networking infrastructure entered into a degraded state</td>
</tr>
<tr>
<td>2014-10-14</td>
<td>SaaS</td>
<td>Google® Drive</td>
<td>Several</td>
<td>Unknown</td>
</tr>
<tr>
<td>2014-11-19</td>
<td>IaaS, PaaS and SaaS</td>
<td>Microsoft® Azure storage</td>
<td>Several</td>
<td>related to an Azure Storage performance update</td>
</tr>
</tbody>
</table>

### 3.8 Existing application migration strategies

Sections 3.8.1 and 3.8.2 describe the existing legacy application migration strategies, *Cold Turkey* and *Chicken Little*, respectively. Section 3.8.3 discusses the commonalities between these different migration strategies. Section 3.8.4 defines the evolutionary requirements to these strategies for cloud migration.

#### 3.8.1 Cold Turkey/Big bang

*Cold Turkey* involves that the legacy system be rewritten completely using modern software techniques as well as hardware. This is a risk prone approach as it requires substantial investment as well as time to execute; during this time the business requirements may change and therefore it is hard to guarantee return. At the same time it is often noticed that the specifications seldom exist and most of the times there are dependencies on other systems which might make the migration unfeasible under the given budget and timeframes. The legacy systems which are generally involved are large as noted by Brodie et al, it may at times take many days to simply take a copy of the database. Management of large projects is hard and as the systems are used by large parts of the organizations any delay as well as unavailability is unacceptable. Brodie et al, have noted that many organizations who have tried to implement this have failed and this has given rise to an alternate strategy which is *Chicken Little*.

#### 3.8.2 Chicken Little/Smooth migration

*Chicken Little* strategy proposes that a legacy system which is to be migrated be divided into different modules and these modules are then individually migrated. This enables the complexity of the entire system to be divided into smaller manageable migration objectives and these are incrementally migrated.

The drawback of this strategy is that it is not always possible to divide a legacy system into sub modules. At the same time if the migration of an individual module fails, only it needs to be redone and not the complete project. Each individual module requires relatively small resources in terms of financing as well as investment of human capital, thus it is easier to get these migrations approved and over a long term the entire system can be migrated without significant impact on day to day business activity.
With the help of gateways in Chicken little strategy guarantees application availability during the migration process. The development of the migrated legacy system is invisible to the client application. When the migration is completed and the target information system has passed all the test criteria the gateway and the legacy application module is transparently removed without any knowledge of the client application.

Figure 6 ■ Chicken Little strategy - migration architecture (ref: DARWIN: On the Incremental Migration of Legacy Information Systems)

3.8.3 Commonalities between Chicken Little and Cold Turkey migration strategies

Both these strategies often deal with migration of legacy systems which lack specification and documentations. Software engineering methods such as reverse engineering [22] are often required to analyze the legacy information systems during which the different modules and their relationships are identified. This is required to develop an abstract system representation. Without this knowledge it may virtually be impossible to migrate a legacy information system and guarantee that the migrated system is able to fulfill all the requirements which the legacy information system fulfilled.

Static and dynamic analysis [23] of the system are also undertaken, where the static analysis is the analysis of the application source code while the dynamic analysis consists of system observation while it is running. The dynamic analysis helps to identify not only parts of the source code which are executed but it also helps to identify application scenarios which are too complex to be identified by simply looking at the source code.

3.8.4 Evolutionary requirements to these strategies for cloud migration

Although both these strategies are generic and can be utilized for migration of any legacy application they do not consider the complexities which are encountered when a legacy application is being migrated to the cloud.

With the help of reengineering and static and dynamic analysis these two strategies help in development of the abstract system representation for the legacy information system being migrated. These in itself are insufficient and do not address the problems in a cloud environment such as:

- Data segregation and security in a multi-tenant environment
- Application availability
- Application portability within the cloud

Thus there is a need to develop legacy migration strategy which will address these issues.
4 Visma Consulting

This chapter contains information about the company where the thesis is being conducted. Chapter 4.1 describes the company and its history. 4.2 describes the company’s vision and its requirements from this thesis. Chapter 4.3 describes the different company migration/development projects which were used during this thesis.

4.1 Visma Consulting

Visma Consulting AB has a long history. It was founded in 1968 under the name “Kommundata” to provide IT-services to the Swedish Local Authorities and to help fulfill their data processing needs. The company was privatized in the middle of 1990’s and since has changed owners and its name a number of times, some of the significant being Dialog, Celsius, Enator, and TietoEnator. In 2007 the company became an independent company under the name SiriusIT and in 2010 it was bought by Visma and came to be called Visma SiriusIT. In 2012 the company again changed its name to the current Visma Consulting AB.

From its inception, the company has the Swedish public sector as its focus area, while that to this day remains the focus area but over the years it has expanded into private sector. The company’s core business area is project consulting. Under project consulting the company takes responsibility of complete projects for its customers and is involved from requirement analysis phase to development, to production and finally management.

The company offers a range of solutions to its clients for example: issue tracking systems, information management systems for internet and extranet, business intelligence solutions, e-services, archiving solutions, integration solutions. Following is the organizational chart which shows the different departments within Visma Consulting’s Sweden, and their key focus areas.

![Visma Consulting’s Organizational structure](image)
4.2 Visma Consulting’s vision and requirements from this thesis.

As the company’s core focus is in public sector it works with many IT systems which have been in existence for a number of years. A number of such systems need to be upgraded and this is seen by Visma as a strong business case to invest in finding new strategies and methods for upgrading the legacy systems. As many of these systems are used by the public sector which often have limited budget, Visma needs to find migration strategies which are cost efficient and reusable in various different projects which are in different scope.

Although these systems were modern and state of the art at the time when originally conceived and have evolved over the years, they have become legacy in their architecture and design which makes it a challenge to keep them updated as well as fulfill new business, legal and statutory requirements. As there is a very high reliance on these systems and because of limited budgets the customers are unwilling to risk making fundamental changes to these systems and have often expressed their desire to modernize these systems iteratively. With legacy system apart from the technological factors one also needs to consider human factors which are involved. The end users have been using the systems for a number of years and any radical change to the system may affect their daily work processes and their efficiency. Thus large system wide changes are often not popular from the management perspective as that not only increases the cost of development and introduces risks in the project planning and execution but it also increases the cost for retraining and maintenance of these systems.

Along with the migration of the legacy system there are also new systems which are being developed. Company wants to find synergies between these migration projects and the new development projects as well as find possible ways to reuse the functionality between applications.

Many studies have identified that a major chunk of the total cost of any IT system, sometimes as high as 70% of total cost [24], are incurred during the maintenance phase. Visma aims to help its customers reduce this costs by modernizing their legacy systems and wherever possible offer cloud solutions. As this will not only result in cost savings for Visma Consulting customers but will free resources for new projects. As in public sector very often new projects need to wait a number of years for budgeting, thus freeing some funds from maintenance will provide Visma Consulting’s customers the opportunity to better utilize these new projects in more value addition services.

4.3 Reference Projects

During the course of this thesis inputs from four company projects were utilized. These projects are described below.

4.3.1 Project 1: Social security system of a large Swedish municipality

Social security system of one of the largest Swedish municipalities has been in production for many decades, it is a critical system for many citizens who require some form of help from the state. The digital system was originally developed a few decades back and it has a multitude of layers after layers of application logic built into it. This has been the result of constant upgrades as well as changes in the laws which the system needs to fulfill. At the same time as and when new digital technologies became accessible they have been incorporated into the system such as possibility to report information using smart devices, digital pen and paper etc. This greatly helps the investigating officers as well as caregivers in helping the citizens as well as reporting back what action they have taken or the help they have provided. The system requires many thousands of hours to maintain and develop and has 3 major releases every year. Each release does not only adds new features but also phases out old unused features as well as bug corrections.

4.3.2 Project 2: Pharmacy solution for small and medium businesses

In the late 2000 the Swedish Government privatized the pharmacy industry in Sweden and it was made possible for the private individuals and entities to sell prescription medicines, provided they
could follow all the legal requirements related to the patient information security and the logistics of handling prescription medicines.

Visma Consulting along with its partner company developed a software solution for this purpose and this is a certified solution which fulfilled all the requirements and was made available to its customers. Today the solution is used by one of the largest private pharmacy companies in Sweden as well as many medium sized and individual pharmacies.

4.3.3 Project 3: Enterprise Content Management (ECM) System for a large Swedish administrative region

A large administrative region in Sweden has an errand management system which is used for tender as well as contract management, for transportation, hospitals as well as environment management. The system is built using a standard product which has been customized to fulfill the customer requirements.

The standard product has the leading position in public sector and is used by many Swedish administrative boards. This at times makes it also a challenge to fulfill the different requirements which an individual customer has. In case of the large Swedish administration region it was the problem with maintenance and management of contracts and tenders as well as searching inside these. Visma consulting developed modularized solutions for these in form of contract management solution as well as content search. The reason for making these solutions modularized was not only because it was not possible to change the standard product but was also to develop a solution which can be provided as a service to other customers who use the given ECM system.

4.3.4 Action research project: VSP, Errand Management System for the Swedish counties.

The pilot project study was conducted on one of the company’s software solutions called VSP, this solution is used to collect and investigate user feedback. This company software is used by 10 Swedish counties and was originally developed in the 90’s. As the system has been in use for a number of years, over its lifecycle VSP has required some complex changes in order to fulfill legal requirements that have been introduced. The current version of the system is in need of modernization in order to fulfill new end user as well as legal requirements. These custom modifications over the years coupled with old technology have made the system hard to maintain. The system was therefore identified as the right candidate for upgrading to a modern technology. VSP also has a large user group and it has therefore been decided that the upgraded system have the possibility to be delivered as a SaaS solution, thus fulfilling all the necessary conditions for the purpose of this thesis.
5 Evaluation Model

This chapter describes the research criteria which are used to create investigation criteria and evaluation criteria. Chapter 5.1 describes how the investigation and the evaluation criteria are related to each other. Chapter 5.2 describes the investigation criteria along with the context, method and problem. Chapter 5.3 describes the evaluation criteria used to verify the results of this thesis.

5.1 Research models

Thesis has utilized investigation criteria along with an evaluation criteria to realize its goals. While the investigation model helps in getting a deeper understanding of the problem area and Visma Consulting’s organizational environment and processes, the evaluation model helps in final evaluation of the results of this thesis and to verify if it has realized its goals. Figure 9 ■ Relationship between research criteria and interview questions, visualizes how these are related to each other.

![Figure 9](image)

**Figure 9 ■ Relationship between research criteria and interview questions**

5.2 Investigation criteria

As shown in the Figure 9 ■ Relationship between research criteria and interview questions the investigation model utilized Interviews 1 and observations. The interview questions and the observation templates used for this are in Section 11.1 Interview Template 1: “Understanding of company’s processes, project selection and selection of key individuals” and Section 11.4 System observation template.

This is undertaken to understand the depth of the problem area as well as to understand what one is actually trying to solve. Thus the first step is to identify at a higher level and then to go in detail level. This is what has been executed with the help of interview and observations.

5.2.1 Context

Context for this study is to understand the complexities which are faced during the migration of a legacy application to cloud infrastructure. As the thesis has been an industrial thesis, the study focused on how the company has migrated its legacy applications before. This thesis has tried to build upon the knowledge that the company gained with execution of these projects along with the knowledge of the problems which have been faced during the course of these migrations.
5.2.2 Method

Method describes the set of rules and criteria which form a repeatable description of how to perform a task and achieve the desired results. Thus the rule to understand the problem which one faces with the migration of legacy application is that one needs to observe a system at a higher level first where one needs to understand not only how the system is built but also how it is used. Then one should consider the constraints that an organization has in terms of budget, resources as well as calendar time to implement the system. One then needs to see the architecture and design of the system as they have been influenced by the previously identified factors. All these decisions and constraints are from the past but they often continue in the migration project also. Criteria to be able to do is through the interview questions as shown in Table 3 – Interview questions, as well as the observation template which was used.

Table 3 ▪ Interview 1 (questions)

<table>
<thead>
<tr>
<th>Project Selection Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. What is the project scope and who is the customer?</td>
</tr>
<tr>
<td>2. What is the project plan?</td>
</tr>
<tr>
<td>3. Can this application be considered a legacy application?</td>
</tr>
<tr>
<td>4. Does this application deal with migration?</td>
</tr>
<tr>
<td>5. Does this application use centralized computing resources or cloud computing?</td>
</tr>
<tr>
<td>6. Do you see any possibility in the near future to use cloud computing in this application?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Previous Experience</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Has any of your previously worked project dealt with legacy application migration?</td>
</tr>
<tr>
<td>2. Has any of your previously worked project involved cloud computing?</td>
</tr>
<tr>
<td>3. What challenges did you face while working in previous projects while dealing with migration and/or cloud computing?</td>
</tr>
<tr>
<td>4. What do you think worked best in previous projects dealing with migration and/or cloud computing?</td>
</tr>
<tr>
<td>5. What experience did you gain from that migration project?</td>
</tr>
<tr>
<td>6. What recommendations do you have for any future legacy system migration and/or cloud migration project?</td>
</tr>
</tbody>
</table>

5.2.3 Problem

Problems are the difficulties and issues that are encountered during migration. The problems which one migration project faces might also be relevant in other project but not always. Thus it is important to analyze a number of different projects to see what problems are common and it is these problems which can be addressed using a standard migration template. This has been the bases for the observations and interviews.

5.3 The evaluation criteria

The evaluation model focused on evaluating SoMLAC method through interviews and action research. Interview templates have been attached in this thesis under Section 11.2 Interview Template 2: “Validation of preliminary strategy against selected company projects” and Section 11.3 Interview Template 3: “Validation of the final SoMLAC strategy” (Appendix).

To evaluate SoMLAC results four different migration projects were utilized. The preliminary SoMLAC model was evaluated during the Interview 2, the questions under section “Review of (preliminary) SoMLAC” and “Suggestions for improvement of (preliminary) SoMLAC”, Table 4
– Interview 2 (questions), were utilized to verify the applicability of the SoMLAC method/strategy. Upon the conduction of interviews the preliminary SoMLAC model was modified.

Table 4 ■ Interview 2 (questions)

<table>
<thead>
<tr>
<th>Review of (preliminary) SoMLAC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. What is your opinion of the model?</td>
</tr>
<tr>
<td>2. If you were to have had it available in the beginning of the migration project, would have used it?</td>
</tr>
<tr>
<td>3. How would it have helped you?</td>
</tr>
<tr>
<td>4. What do you think that might have/does not work?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Suggestions for improvement of (preliminary) SoMLAC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Do you have any recommendations?</td>
</tr>
<tr>
<td>2. Will you use this in any future/current migration project?</td>
</tr>
<tr>
<td>3. How will you rate the model with respect to generality and reusability?</td>
</tr>
</tbody>
</table>

The modified SoMLAC model was then revalidated during Interview 3, during this interview questions under the section “Addressal of concerns (preliminary SoMLAC migration strategy)” were utilized to confirm that the modified model incorporated the changes which were requested. The interviewees were then requested to provide any further suggestions to the SoMLAC using the questions under section “Suggestions for improvement”. Finally the interviewees were asked about their views about reusability of SoMLAC and if they would use the model in their future migration project. These questions are grouped under section “SoMLAC reusability”. Table 4 – Interview 3 (questions), shows the questions asked during Interview 3.

Table 5 ■ Interview 3 (questions)

<table>
<thead>
<tr>
<th>Familiarity with SoMLAC migration strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Have you looked at the final cloud migration strategy/model?</td>
</tr>
<tr>
<td>2. What is your opinion of the model?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Addressal of concerns (preliminary SoMLAC migration strategy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Did you have any concerns with the preliminary model?</td>
</tr>
<tr>
<td>2. Have your concern been addressed in the final model?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Suggestions for improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Will you like to change something/ your recommendation?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SoMLAC reusability</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Is the model complex or is simple to follow?</td>
</tr>
<tr>
<td>2. Will you use this in any future/current project?</td>
</tr>
<tr>
<td>3. How will you rate the model with respect to generality and reusability?</td>
</tr>
</tbody>
</table>

As no two migration projects are alike, the interviewees provided answers to the questions in context of the projects they had been working on. Apart from interview questions the SoMLAC checklist along with SoMLAC workflow diagrams were also utilized during each interview. SoMLAC checklist is present in Chapter 6.5 SoMLAC compliance checklist.

SoMLAC checklist was then used in one of the company project as action research with an aim to validate SoMLAC in a live migration project and to see if the respondents found it helpful and if they will use the model in other migration projects in the future. This was complemented with comparison of SoMLAC with similar research in this area.
6 Strategy for Migrating Legacy Applications to Cloud (SoMLAC)

This chapter defines the SoMLAC migration strategy. Chapter 6.1 provides an overview of the SoMLAC migration. Chapter 6.2 describes the Phase 1 where a legacy application is migrated to cloud infrastructure. Chapter 6.2.1 describes the different steps in the Phase 1 while Chapter 6.2.2 describes the different aspects that need to be considered while a legacy application is being migrated to the cloud. Chapter 6.3 describes Phase 2 of SoMLAC where a PaaS is developed. Chapter 6.4 describes Phase 3 where SaaS solutions are developed. Chapter 6.5 contains the SoMLAC compliance checklist.

6.1 Overview

Strategy for Migrating Legacy Applications to Cloud (SoMLAC), is a methodology to help organizations move their applications to the cloud. Although the cloud infrastructures have been commercially available for a few years and hold the promise of optimizing the IT needs of the businesses, the businesses and organizations have been hesitant in adopting it. This can be attributed to the huge investments which they have made in their private datacenters and to the lack of knowledge as well as understanding of cloud infrastructure. The businesses are so dependent on their current software solutions that they are not willing to abandon these and adopt radical new cloud solutions.

SoMLAC is to help organizations make this transition of moving their existing business systems from traditional local data centers to the cloud infrastructures. SoMLAC helps businesses when making a transition plan for these business systems, as well as it helps businesses to be better prepared when the actual transition is being made.

Figure 10 ■ Overview of SoMLAC migration strategy
Three phase migration (Move, Transform and Build - MTB)

Cloud projects can be classified into two categories.
- New greenfield projects
- Migration of existing solutions to the cloud infrastructure.

The first category of projects, even though are challenging, are still relatively simple compared to the migration of existing applications. As while the greenfield applications are being designed, the different cloud characteristics are factored in the application design and architecture, unlike the legacy applications, which were never designed to be hosted centrally in a multi-tenancy environment. At the same time, when these legacy applications were designed, infrastructure security was not an issue as the applications ran in secure & trusted environments. As soon as one considers cloud based infrastructures many of these presumptions become some of the most complicated issues which need to be addressed and this often results in redesigning of the entire legacy application.

Being inspired from traditional Chicken Little migration strategy, SoMLAC proposes to migrate the legacy applications to the cloud in an iterative manner. This strategy not only reduces the risks involved with migration but it even allows the organization time and means to develop its knowledge and experience of handling applications in cloud infrastructure. The organization learns while moving from one SoMLAC phase to the next.

The three phases proposed for cloud migration are Move, Transform and Build (MTB)

a. **Move** – This is the first step, which proposes that the organizations should begin by simply moving application from local infrastructure to the cloud. While making this transition the organization will have tackled some of the very basic questions around the cloud infrastructure such as data security and stability of the cloud infrastructure. The aim of this phase is simple; move the current legacy application to the cloud with as little changes as possible and without making it cost inefficient.

b. **Transform** – Once the legacy application has been successfully hosted on the cloud infrastructure, the next step is to successively transform it from a traditional 3-tier or n-tier architecture to SOA architecture [25]. SOA is best suited for distributed environment such as cloud infrastructure and has even been referred to as the architecture of the future [26]. In SOA it doesn’t really matter if the service is hosted locally or in the cloud. This transformation is successive and employs the strategy that any future modifications and functional changes should be modularized and wherever possible independent reusable web services should be created. To be successful it is imperative that the developed web services are independent and well documented, as over a period of time these independent web services will create a platform which may then be used to develop any future application for the given domain. Of the three phases of SoMLAC, this is the most complex phase and can span over a number of years.

An example of such a scenario is that during the migration of legacy system and its transformation in the cloud infrastructure, independent services such as user authentication and access control, document generation, communication services are created which may virtually be used in any future application.

c. **Build** – This stage is the natural successor to the transformation phase. During this phase new parallel applications can be created by utilizing previously created independent reusable functionalities via respective web services as well as creating more reusable independent functionalities for the future, thereby creating an application ecosystem. The ecosystem if mature enough can be used to create applications for multiple different user groups as well. The user group may consist of the original legacy application user or may be completely different.
The second phase of SoMLAC visualizes the different high level steps which are to be undertaken while applications are being developed and migrated to the cloud utilizing the cloud platform. The platform itself evolves along with the applications which are migrated as well as developed for the cloud.

The third and final phase of SoMLAC visualizes what basic changes need to be considered when an application is being transformed from a single customer application to one which is offered as a SaaS solution to multiple customers.

6.2 Phase 1 Move: (Legacy Applications to IAAS)

The aim of this first phase is not simply to move the current legacy application to the cloud infrastructure with as few changes as possible, but is also to setup the basic framework which the organization shall use during any future migration of legacy applications as well as creation of cloud based applications. It is therefore imperative that this migration is achieved without making it cost inefficient.

During this first step towards cloud adoption where the legacy applications are moved to IAAS infrastructure, the decisions made by the organizations shall often result in selection of the preferred cloud service provider, as well as define the policy framework and other aspects such as end-user authentication, data security, activity logging, support and incident handling, price model and its cost effectiveness.

![Figure 11 - SoMLAC Legacy application to IAAS](image)

6.2.1 Steps

The first phase of the SoMLAC consists of four steps:

- Pre-study
- Decision making
- Migration planning
- Execution

The pre-study step is where an analysis related to the application access, accountability, security infrastructure and financial viability are conducted. These provide a better picture to the
management for the decision making process as this step helps in early identification of the problems and complexities which the application migration might encounter.

The decision making step is where the final decision is made whether to go ahead with the migration of the legacy application or not.

Migration planning step is the consequence of the decision making step where it has been agreed to go ahead with the migration of the legacy application. During this step a detailed project plan is developed which includes the specification of the different changes which are required to be made to the legacy application. Once this is completed this migration planning phase also contains a decision making point based on the results of the detailed project specification. The aim of this decision making is to verify the validity of the initial financial and technical viability of the migration project. It may so happen that even though the legacy application requires many complex changes before becoming ready to be migrated to the cloud, but because of the presence of a strong business case a decision to move to the next execution stage is made.

The final step is the execution step, where the application is actually migrated and the different application modules such as access management are developed.

6.2.2 Aspects

The aspects which SoMLAC identifies and proposes to be investigated during this migration phase are:

- Application access and architecture
- Application responsibility and accountability
- Availability
- Data security
- Portability
- Future cost effectiveness

6.2.2.1 APPLICATION ACCESS AND ARCHITECTURE

A legacy system often has two types of users, internal and external. The boundary which defines who is internal or external is often based on simply who is inside the intranet and behind the firewall and who is outside. Any user who is inside the organizations intranet is considered internal user while any other user who is accessing the system from outside the firewall is considered external. Often internal users are trusted and authentication mechanisms for them are simpler as compared to the external users who are untrusted and often more robust authentication mechanisms are used such as two-factor authentication [27]. This legacy infrastructure setup is shown in the Figure 12.

Cloud infrastructure is completely different from traditional IT infrastructure where all users are considered external irrespective of whether the user of a cloud application is inside the intranet or is in extranet. Thus every user be it internal or external is a potential risk and needs to be authenticated via “identity and access management system”. This is illustrated in the Figure 13.

This nature of the cloud has a significant effect on migration strategy for legacy applications as often the legacy applications were designed for internal trusted users. Thus when these legacy systems are migrated to the cloud, even these previously trusted users need to be authenticated just as any other external users. This at times is needed to be implemented to meet statutory and legal requirements, such as, European Union (EU) Data Protection Directive.

Thus even though the basic application logic does not need to change with migration to the cloud infrastructure, the security architecture has to be built from ground up. Therefore any planned migration of legacy application should have this change in security architecture as one of the most significant activity and allocate sufficient resources to this phase.
Figure 12 ■ Traditional IT infrastructure

Cloud

Figure 13 ■ Cloud Infrastructure

6.2.2.2 APPLICATION RESPONSIBILITY AND ACCOUNTABILITY

An organization using the cloud infrastructure can transfer responsibility but not accountability. While the infrastructure availability and security remains within the purview of the cloud infrastructure service provider who is responsible for the maintenance and upkeep of the infrastructure, it is IT-department of the organization using the cloud infrastructure, which remains responsible for every other aspect of the application hosted on the cloud infrastructure and it continues to remain accountable towards the end users of the application.

When the organization goes from simply using the infrastructure provided by the cloud service provider, to using the platform services offered by the cloud service provider for developing cloud applications, the responsibility begins to shift from the organization towards the cloud service...
provider as it is the cloud service provider which is directly responsible for the platform services. E.g. of such ready to use platform service is Amazon® Payments.

Similarly if the organization utilizes a ready to use cloud solution from the cloud service provider, the complete responsibility of the software lies with the solution provider and the organizations IT-department is only responsible for the coordination with the end users as well as conformity of the SLA (Service Level Agreements) with the solution provider. An example of such ready to use cloud solutions are Google™ Enterprise mail and the Microsoft™ Office 365.

6.2.2.3 AVAILABILITY

A cloud infrastructure is inherently more stable in terms of availability as the information is distributed across multiple data-centers, which are geographically distributed. This distribution is necessary for redundancy and recovery purposes. This provides insurance from the possible disaster management scenarios such as those experienced by companies during the hurricane “Sandy” which hit New York City in 2012 [17].

Today most of the large cloud infrastructure providers have their data centers at many different places across the globe such as Microsoft Azure™ which has presence in 17 different regions [28] while Amazon Web Services™ has a presence in 11 regions [29]

At times there are some legal directives such as EU data protection rules [30] which might restrict the use of this data transportability between regions. These directives have been designed with the purpose of maintaining privacy as well as accountability of personal data. As per the principle of accountability, it is the responsibility of the organization utilizing cloud resources and storing personal information to do diligent work and determine that all such requirements are fulfilled.

![Figure 14](image.png) The flooded lobby at the Verizon site at 140 West Street during the height of the storm surge Monday night (Photo: Verizon)

6.2.2.4 DATA SECURITY

Data security in the cloud environment is one of the most talked about topic in relation to the cloud infrastructure. Traditionally information was stored in local datacenters which were governed by the local IT-departments. In cloud this is not the case, the information is stored in remote data-centers owned by the cloud vendor. These data-centers often are shared between organizations in a multi-tenancy environment.

Thus an organization utilizing 3rd party cloud infrastructure needs to protect its information from the following:
• Snooping: As often these data centers are in locations other than the local premise, the information is communicated over the internet.

• Unauthorized access by the service provider: The information is stored on the servers owned by the service provider, thus there should be adequate mechanisms in place which prevent unauthorized access to information even by the personal who are administering these servers.

• Unauthorized access by other tenants: As the cloud resources are stored along with other tenants, it should be considered that potentially the other tenants may gain access to information accidentally and how this can be prevented. A hypothetical scenario is where the application information is stored in memory which may later be allocated to another cloud application. Thus the second cloud application can potentially access the information stored by the first application.

As application data is one of the main focus areas of concern when organizations are contemplating migration of applications to the cloud, SoMLAC suggests that the organizations consider at least one of the following different data security solutions when migrating, an encrypted database, an encryption service or a hybrid secure cloud.

![Figure 15](image)

**Figure 15** The traditional layered approach to enterprise security, from *Computer Fraud and Security* (Volume 2012, Issue 8, August 2012)

### 6.2.2.4.1 Encrypted Database

Today many of the database servers such as Microsoft SQL Server have inbuilt capability to store all the information in an encrypted form [31]. Such techniques ensure that even if any 3rd party gets access to the database files, the information stored in these database files remains inaccessible to them. In case of Microsoft SQL Server this technique is called Transparent Data Encryption (TDE) which performs real time I/O encryption of the data and log files. The encryption is achieved with the help of a symmetric encryption key called Data Encryption Key (DEK). A corresponding certificate for the key is stored in the master database of the server. An asymmetric algorithm may also be used for encryption where the master key may be stored in an Extensible Key Management (EKM) module or directly in the master database.

Once the database has been encrypted it means that in case of symmetric key algorithm the database files can only be accessed on the server instance on which the key certificate has been installed and in case of asymmetric key algorithm the database files can only be accessed with the help of the Master key. Thus it is important that both the certificate and the master key are not stored in the same environment as the database, and the organization may even choose to store them only on local premises and not in the cloud infrastructure. This ensures that the system which is cloud based and stores information can comply with many laws, regulations and industrial guidelines.
It should be noted that even though the information stored in the database is stored as encrypted, it is still prone to illegal access when it is being transmitted from the database to the application. Thus adequate security mechanism in form of transport level encryption such as those provided by HTTPS should be employed.

6.2.2.4.2 Cloud encryption service

Applications at times not only store information in the database but also store files in the file system. It is therefore necessary that the information stored in the file system is also stored securely. At the same time it is cumbersome to handle two different types of encryptions in the application and therefore to simplify this, SoMLAC proposes that the organizations create an encryption web service where this web service acts as a bridge between the application and its data (database or file system).

All communications with the web service are using secure protocols such as https, which guarantees that no unauthorized access to application database is made. The web service should use an encryption mechanism such as asymmetric key encryption to encrypt and decrypt information on the fly.

The advantage of using an asymmetric key encryption is that the master key can safely be stored in the companies/organizations local environment or in a secure key management solution such as SafeNet® Enterprise-wide encryption key management solution [32] or Thales Encryption Key Management System [33] or Barbican, the open source key management system for OpenStack [34].

As the proposed service is generic in nature, this can be reused in any other application which the organization wishes to host in the cloud infrastructure.

6.2.2.4.3 Hybrid Secure Cloud

This is one of the highest forms of data security which can be achieved when it comes to cloud infrastructure. The purpose of this is to store all application related information on a local storage inside the organizations trusted network such as the intranet with DMZ or a private cloud. Information stored in this local storage is accessed as and when needed by the application and sent back to the storage after processing; it is never stored in the cloud infrastructure. To ensure information security during transportation between the cloud application and the local storage, a secure communication protocol such as https is employed.
6.2.2.5 PORTABILITY

This is one of the least talked about aspect when it comes to cloud computing, but at the same time probably one of the most important factors which an organization needs to analyze when migrating to the cloud; as this might not only affect the long term cost viability of the migrated applications but it may also affect the organizational existence in case the cloud service provider ceases to exist.

In general portability within the cloud services refers to the ability to move resources/service hosted inside the cloud; it may be within the cloud service providers own infrastructure or may as well be movement of resources between different cloud providers. Large organizations have been using virtualized environments for some years now. Many such organizations which wish to move to cloud infrastructure therefore wish for a simpler mechanism to move these virtual machines to the cloud. Many of the cloud service providers identified this and created migration utilities which help organizations convert their locally hosted virtual machines into a cloud service provider’s compatible format which can then be hosted in the cloud.

The problem arises when one wishes to move these resources back to the lost storage or from one cloud service provider to another cloud service provider. The reasons may vary, it may be because when the organization launched its service it did not know how well it will be accepted in the market and therefore choose to use cloud infrastructure which is elastic in nature and can be adjusted to the demand, thus the organization would like to migrate the solution from the cloud to local infrastructure after the user pattern has been stabilized or because it feels that there is a business need to have the service hosted locally. Another reason for migration from one cloud service provider to another might simply be because the cloud service provider is no longer competitive compared to the other cloud service providers. Finally the reason might simply be that the cloud service provider plans to exit the business and therefore all the customers who have been using that cloud service provider’s infrastructure should have the possibility to migrate their investment from this cloud service provider to another.

Some of the problems related to portability are because when the cloud was in its infancy and there were no standards which meant that each service provider had their own custom solutions and it is hard for them to export information from their custom hosting into a standardized format which can execute outside their environment.

Many cloud service providers have now begun to provide means to enable such migration such as Microsoft Azure allows for the virtual cloud infrastructure to be exported in form of Virtual pc images which can be run locally in organizations infrastructure or maybe then exported to some other cloud service provider. Thus SoMLAC suggests that any organization migrating to the cloud

![Figure 17 Secure hybrid cloud](image-url)
should seriously consider this aspect and wherever possible should choose a cloud service provider who supports portability.

![Figure 18 - Portability of virtual machines between different environments](image)

### 6.2.2.6 FINANCIAL VIABILITY

As mentioned earlier the thesis shall only consider the cost viability objectively as cost can often be negotiated between the cloud provider and the organization planning to migrate to the cloud.

Some of the factors on which the cost viability of a SaaS solution is dependent are:

- Data storage location
- Data security requirements
- Support and SLA

Data storage location affects the costs as the infrastructure providers have different costs involved in establishing and maintaining data centers in different locations. In order to fulfill legal requirements at times the organizations need to select a data center in a given geographical location, e.g. it is mandatory for organizations located in EU and storing personal information to guarantee that information is stored within European Economic Area (EEA).

The more stringent the security requirements are, the more it often costs as in such scenarios the cloud infrastructure provider might not be able to share some resources with other clients and the resources become dedicated to one customer. As in traditional data-centers the cloud infrastructure customer pays in relation to the SLA and the support requirements they have.

Apart from the above, new cloud infrastructure providers often have an aggressive pricing model which is an advantage for organizations deciding on migration to the cloud. New cloud service providers do not only offer a better pricing model but at times also have features which are not yet available with their competitors.
6.3 Phase 2 Transform: IAAS to PaaS

Once an organization has completed Phase 1 of SoMLAC and has migrated an application from local environment to the cloud, the organization would have answered the biggest questions related to its application data ownership, security along with questions related to the management and reliability of its application in cloud infrastructure. The organization will have established secure application data storage locations and routines as well as secure communication between the application and its end users.

All these knowledge and utilities developed for this purpose such as encryption web-service for secure data storage, encryption enabled databases, user authentication and role management web-service can be reutilized when other applications are migrated to the cloud infrastructure, thus creating a platform or PaaS for other applications which are to be developed for the cloud.

Some of the public cloud service providers have even developed general platforms for their customers. The customers can not only host their solutions in cloud service provider’s infrastructure but can use their pre-developed services for rapid application development. An example of a service provider providing a PaaS for rapid application development is Microsoft™ Azure®. Azure provides an environment where applications based on ASP.NET can be developed and hosted. Some of the other services which Microsoft provides in its Azure platform are [35]:

- Hosting of web applications
- Hosting of mobile services
- Hosting of online databases
- Hosting environment for very large data commercially known as HDInsight.
- Media services for streaming audio and video.
- Azure service bus: a cloud messaging system which can be utilized for connecting applications, services and devices.
• Visual Studio Online: a cloud based application development platform.

While other service providers such as Amazon Web Services (AWS) provide many services [36] which are unique to it such as Amazon FPS (Flexible Payment Service) and Amazon CloudSearch, a search service which provides customers search functionality for their applications.

6.4 Phase 3 Build: PaaS to SaaS

![SoMLAC PaaS to SaaS](image)

Once an organization has created a PaaS or has gained experience in developing, hosting and managing cloud applications, the organization might as well develop applications which are generic and it can offer these services to other customers, thus evolving from being a consumer of cloud services to a cloud service provider. An example of SaaS is Adobe™ Creative Cloud [37], Microsoft™ Office 365 [38] or Google™ Docs [39].

Often companies which do not offer IT-services are more concerned with developing services for their internal use rather than for others and therefore have little motivation in moving to this stage.

On the other hand, for the organizations with core interest in developing and providing IT-services to other organizations, this is the final goal, where the organization can create an application for one customer but if possible reuse it and provide it to other customers. The advantages of SaaS solutions have been well documented; it provides a means where the organizations can not only provide software but can also manage it at a fraction of a cost, as a SaaS solution does not need to be distributed and the organization does not need to manage multiple versions of the same software. At the same time the customers only need to pay for their software usage, this often is much less than the cost they might have paid in case the software was purchased. The advantage for the SaaS provider is that it can increase its customer base thus increasing its overall revenue.

6.5 SoMLAC compliance checklist

SoMLAC checklist is composed of three sections and helps an organization during initial planning and decision making process. The checklist can also be used to validate if a cloud application meets the obligations that an organization has towards maintenance of its customer information.

The first section “Phase 1 (Legacy to IaaS)” contains the checklist related to initial migration of a legacy application to the cloud. It helps an organization determine the impact of moving the application to the cloud, in selection of a cloud service provider and in identifying functional and non-functional requirements such as application access, availability, accountability and responsibility, security architecture and portability. The second section “Phase 2 (IaaS to PaaS)” contains the checklist which helps an organization in development of a platform for development and migration of other applications. The third and final section “Phase 3 (SaaS)” helps an organization determine the factors which it needs to consider before developing SaaS solutions.
<table>
<thead>
<tr>
<th>Organizational impact</th>
<th>Cloud service provider selection criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>- The application becomes widely public and widely distributed?</td>
<td>- Where is the data stored? (physical location and data center configurations) (updated)</td>
</tr>
<tr>
<td>- An employee of cloud provider accessed the application and/or application data?</td>
<td>- How often is the data backup taken?</td>
</tr>
<tr>
<td>(updated)</td>
<td>- Where is the backup data stored?</td>
</tr>
<tr>
<td>- The process or function is manipulated by an outsider?</td>
<td>- Who has access to the infrastructure and data?</td>
</tr>
<tr>
<td>- The process or function failed to provide expected results?</td>
<td>- What access do they have? (new)</td>
</tr>
<tr>
<td>- The information/data were unexpectedly changed?</td>
<td>- Access logging? (new)</td>
</tr>
<tr>
<td>- The application was to be unavailable for a period of time?</td>
<td>- What is the Incident Response Lifecycle?</td>
</tr>
<tr>
<td></td>
<td>- When and who did the last Security audit?</td>
</tr>
<tr>
<td></td>
<td>- Which industry standard was followed ISAE 3402/SSAE 16 (replaces SAS 70), PCI, HIPAA and ISO 27002 (updated)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Application functional requirements</th>
<th>Application non-functional requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Application access and architectural requirements.</td>
<td>- Application responsibility and accountability</td>
</tr>
<tr>
<td>o Identity and access management system for the application needs to be developed or sourced</td>
<td>o Clearly define the responsibilities of organization and that of the cloud infrastructure service provider</td>
</tr>
<tr>
<td>o Where is the data center located?</td>
<td>o Define SLA and incident management</td>
</tr>
<tr>
<td>o Do any statutory and legal requirements need to be fulfilled?</td>
<td>o Data privacy and accountability is maintained?</td>
</tr>
<tr>
<td>- Data security</td>
<td>o Application and system logging</td>
</tr>
<tr>
<td>o Application data stored in database is encrypted and protected?</td>
<td>- Availability</td>
</tr>
<tr>
<td>o Application accesses its data through encryption web-service?</td>
<td>o Are backup routines defined?</td>
</tr>
<tr>
<td>o A secure communication protocol (HTTPS, Secure FTP) is used for communication between cloud application and clients (New)</td>
<td>o How can the system be restored from backup?</td>
</tr>
<tr>
<td>o Are encryption keys and/or certificates used for securing application and infrastructure stored either in local infrastructure or a key management system?</td>
<td>o How long does system restore take?</td>
</tr>
<tr>
<td>o Are virtual cloud infrastructure hard-drives are encrypted?</td>
<td>o Are backup routines defined?</td>
</tr>
<tr>
<td>o Only a limited personal have access to cloud infrastructure and their activities are logged? (updated)</td>
<td>o Where is the backup located?</td>
</tr>
<tr>
<td>o Who has access to application data and logs? (updated)</td>
<td>- Portability</td>
</tr>
<tr>
<td></td>
<td>o Can existing virtual machines be migrated to cloud infrastructure?</td>
</tr>
<tr>
<td></td>
<td>o Can virtual machines be moved within different data centers owned by the cloud infrastructure service provider?</td>
</tr>
<tr>
<td></td>
<td>o Is the application, application data and infrastructure portable?</td>
</tr>
<tr>
<td></td>
<td>o Can the organization retrieve the cloud image in a format which can run inside local infrastructure or inside infrastructure provided by another cloud infrastructure service provider?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Phase 2 (IaaS to PaaS)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>- Is the Identity and access management (IAM) system reusable in other applications?</td>
<td></td>
</tr>
<tr>
<td>- Can the previously developed data protection mechanisms be reused between different applications?</td>
<td></td>
</tr>
<tr>
<td>- Can platform service guarantee data isolation between applications?</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Phase 3 (SaaS)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>- Can application guarantee data isolation for different customers?</td>
<td></td>
</tr>
<tr>
<td>- Which statutory and legal requirements the application needs to fulfil?</td>
<td></td>
</tr>
<tr>
<td>- Does the application meet statutory and legal requirements?</td>
<td></td>
</tr>
</tbody>
</table>
7 Model evaluation within the company

This chapter describes evaluation of SoMLAC within the company. Chapter 7.1 describes how the evaluation was conducted within the company. Chapter 7.2 contains the three different projects where the SoMLAC was evaluated. Chapter 7.3 contains information about action research. Chapter 7.4 describes the changes which were made to SoMLAC during model evaluation.

7.1 Evaluation overview

To test the SoMLAC model a series of interviews were conducted. A number of Visma Consulting employees have been part of this thesis. Their responsibilities range from being decision makers, coordinators, solution designers, implementers all the way to those responsible for support and maintenance. They are department chiefs, sales representatives, business consultants, project managers, architects, developers, maintenance managers.

To test the final template, each individual was provided with the model and checklist and was requested to give feedback on if they think SoMLAC helps them in decision making, defining project scope, design and implementation of the migration strategy for the application they are responsible for. They were asked to provide feedback if they can correlate to the checklist tasks which have been proposed in SoMLAC and if any changes are requested.

Four of the company projects were used for the evaluation of SoMLAC

- Project 1: Social security system of a large Swedish municipality
- Project 2: Pharmacy solution for small and medium businesses
- Project 3: Enterprise Content Management (ECM) System for a large Swedish administrative region
- Project 4: Action research project: VSP, Errand Management System for the Swedish counties

7.2 Interviews and surveys

Individual one on one meetings, coffee table discussions as well as group discussions were held where the SoMLAC checklist was debated upon.

7.2.1 Project 1: Social security system of a large Swedish municipality

For the purpose of this thesis I asked the architects, the project managers, developers, test managers about the future of the system as well as how do they plan to move it to cloud.

The system has been developed a few decades back and although it has moved to the newer versions of the programming language utilized to develop the system and has more and more integrations with other systems, the basic architecture has not changed much. Most of the application logic is built into the graphical user interface which itself is tightly coupled with the backend database. For a few years now more and more parts of the newly developed modules as well as old logic are being moved from the application to the web services.

Following are the results of the SoMLAC compliance checklist for this project:

**Phase 1 (Legacy to IaaS)**

*Organization impact:* upon interviews and system observation it was found that the information contained in the application is highly confidential in nature. The information contained in the application contains information about the local inhabitants of the municipality. Information pertains to the social welfare such as child related issues, drug abuses, physical and mental disorder, family issues etc. Any compromise to this information can result in a significant impact on social and economic security of the person concerned.
Cloud service provider selection criteria: because of stringent legal requirements only a private cloud solution can be utilized.

Application access and architectural requirements: the system has been in production for a number of years; the technology used as well as the architecture of the system requires significant changes for it to become cloud compliant.

Application responsibility and accountability: the maintenance organization and the political organizational cannot afford to move the responsibility and accountability of the system to a 3:rd party organization. Thus in case of a cloud solution only a private cloud solution shall be considered.

Availability: as the livelihood of many individuals depends on the system, there will be certain periods of the month where the unavailability will be significant. Many elderly and functionally challenged individuals receive help through the social security program and any system unavailability will mean that many people may be denied help which they have been guaranteed under various different laws.

Data Security: this was discussed under the organization impact the system will have in case there was a leak of information. Many of the secure communication technologies are already employed in the current system.

Portability: it was identified in the context of this application only a private cloud solution will be utilized and in such cases only the aspect of moving within the same cloud service provider may become relevant and the other questions were not relevant for this project.

Phase 2 (IaaS to PaaS)

There is no possible reusability scenario for this system and thus creating a platform was found to be not applicable.

Phase 3 (SaaS)

As the system is only used by the Swedish municipality thus there is no requirement for making the system as a SaaS solution.

Conclusion: after many discussions it was found that many of the information related to the migration was already present with different individuals involved in the project group but significant impact which SoMLAC had was gathering all this information at one place and providing a template for future decision making process.

There was a strong consensus that SoMLAC shall help significantly in decision making as well as defining the architectural changes which shall be required for any future cloud migration.

7.2.2 Project 2: Pharmacy solution for small and medium businesses

This project has already completed, the project has been used to verify the SoMLAC model. To see if SoMLAC complies with the decision making process which was utilized during the project execution and if SoMLAC could have helped if it was to be available when the project was being executed. Following are the results of the SoMLAC compliance checklist for this project.

Phase 1 (Legacy to IaaS)

Organization impact: a study of the organization impact was conducted before the execution of the project and not only the application data but the application access itself was critical. As the application contained not only the application data but also was integrated to many other systems which contained information such as patient information.

Cloud service provider selection criteria: this was conducted and because of stringent legal requirements only cloud service provider which could guarantee that the information was going to reside in a datacenter within the Swedish jurisdiction was selected.
Application access and architectural requirements: As it was a newly developed application it met most of these requirements out of the box.

Application responsibility and accountability: there is a clear definition of the responsibilities and accountability of the different organizations which are involved.

Availability: System availability is critical and therefore two different datacenters are utilized.

Data Security: Patient information requires one of the highest levels of data security and the application has employed most of the SoMLAC proposed data security technologies.

Portability: There are a very few cloud service providers which fulfill the legal requirements to store patient data and therefore this was not considered.

**Phase 2 (IaaS to PaaS)**

There is no plan to use the pharmacy application as a platform, therefore IaaS to PaaS phase is not applicable for this project.

**Phase 3 (SaaS)**

This phase is applicable to this project as a commonly hosted application provides pharmacy solution to small businesses. SoMLAC questions such as data isolation for different customers and fulfillment of statutory requirements were relevant in this project and were considered when the solution was being developed.

Conclusion: SoMLAC closely follows the decision making steps which were undertaken in the project. At the same time during the interviews it was noted that some of the decisions were discussed later during the project execution phase but incase SoMLAC was to be utilized these could have been made earlier which may have meant that the project execution time was shortened.

As the systems was relatively recently designed and developed it utilized modern techniques and SOA architecture, therefore it cannot be termed as a legacy system migration. This project faced many challenges, especially when it came to the individual pharmacies, the solution requires many servers and integrations, government systems, supplier systems as well as logistic company systems. It was not cost efficient for each individual pharmacy to have such a huge investment. In order to provide this software solution as a service Visma Consulting redesigned the system for customer data segregation and hosted it centrally.

7.2.3 Project 3: Enterprise Content Management (ECM) System for a large Swedish administrative region.

Today the modules need to be installed locally where the ECM product is installed. It has been planned that in future the solution shall have the possibility to be installed at a central location and be provided as a service. Thus it will become a hybrid cloud solution and it is believed that during the migration the SoMLAC model shall be helpful. Following are the results of the SoMLAC compliance checklist for this project.

**Phase 1 (Legacy to IaaS)**

Organization impact: Many questions asked were found to be relevant to the project and some shall be answered when a centralized hosting solution is developed.

Cloud service provider selection criteria: The template provides a criteria which shall be used when selection of the centralized hosting infrastructure provider is being made.

Application access and architectural requirements: The system is a module to a larger system and the access and architectural requirements are already fulfilled.

Application responsibility and accountability: this shall be helpful when SLA agreements are to be conducted.
**Availability:** System availability is related to the availability of the parent system to which ECM is a module.

**Data Security:** many of the security requirements are fulfilled while others related to the cloud infrastructure shall be considered when a centralized solution is being developed.

**Portability:** This shall be discussed when the development project is initialized.

**Phase 2 (IaaS to PaaS)**

As the module is made on top of a standard system, it will be relevant that when a centralized solution for the ECM is being developed. The centralized solution be developed using architecture where the same can be reused to develop other modules for the standard system.

**Phase 3 (SaaS)**

It will be important to guarantee data isolation for different customers when a centralized solution is being developed and therefore, it was found that SoMLAC questions are important to consider when the pre-study and planning is being considered.

**Conclusion:** During the interviews there was strong agreement with SoMLAC, at the same time it was suggested that the Phase 2 and Phase 3 checklists need to be more comprehensive same as that for Phase 1.

### 7.3 Action research

SoMLAC was used for action research in one of Visma Consulting projects where the company was tasked by 10 Swedish counties to find a solution to upgrade their legacy application called VSP. During the action research the SoMLAC was utilized during decision making and identification of the different cloud characteristics. This action research was employed after Visma Consulting decided to go beyond the original task relating to simple migration of application to the new version. Visma Consulting also undertook the task to analyze how to provide VSP application as a cloud based solution where Visma was not only responsible for providing the
product but was to also be responsible for hosting it for the counties. For this purpose SoMLAC checklist and interview templates were used to understand the user and system requirements.

Figure 2.1 shows how the SoMLAC model was utilized in this action research project.

The counties found that this was in their benefit if they were to use centralized hosting environment such as cloud infrastructure as this would not only increase the efficiency of receiving support for the product but shall also be more economically viable in long term. In the proposed centralized hosting environment the counties have made it evident that the information of one county should not be accessible by the other counties.

7.4 Points of change

Evaluation of the model with the interviews in Phase 2 resulted in some minor modifications as well as workflow modifications to the preliminary SoMLAC. During these interviews it was found that although the model was found to be effective and reusable in many projects, there were some scenarios were it did not work. The problem identified was how to follow the model even though the legacy system being migrated required many complex changes to its architecture and design before becoming compatible for cloud migration. This decision making process needed to be addressed in the preliminary migration strategy.

Minor modifications required changes to the checklist where the text formulation has been updated. This was as a result of user feedback during the Interview 2 which related to the validation of the preliminary model. The feedback has resulted in changes to the checklist, as it was required that at places the text be made more generic in order to be application in different application contexts, in other places the checklist needed to be more thorough. All the text in the checklist that has been italicized and underlined has been added or modified after end-user feedback.

Major changes to the Workflow modification has been in terms of addition of a new step in the migration phase. Where in presence of a strong business case a decision may still be made to go ahead with migration of a legacy application and to make extensive changes to the legacy system before it becomes compatible for cloud migration. These changes have been shown in Figure 22.

*Changes made to the preliminary model*

![Figure 22: Changes made to the preliminary model](image)
8 Discussion

In this chapter the results of this thesis work are discussed. Chapter 8.1 discusses the problem domain. Chapter 8.2 discussed the method results. Chapter 8.3 describes how the thesis was conducted at Visma and the challenges faced. Chapter 8.4 compares the results of this thesis with other related work in this field.

8.1 Discussion

Today the cloud is not on the fringes but has rather become a mainstream. A survey conducted by RightScale [40] has identified that today the cloud is ubiquitous, over 94% of all responding organizations have been using the cloud as IaaS. It should be noted that statistically the number of issues relative to the number of cloud services available is lower than the previous years, signifying that the industry is moving fast in resolving the new challenges which are identified after each incident, thus improving the quality and reliability of the cloud resources at large.

Even though this is true, there is one fundamental problem which the organizations are facing and that is that they are heavily invested and dependent of their current IT-systems. Many of the times it is unthinkable for organizations to re-implement these systems as the risks involved outweigh the benefits. Thus organizations need to be given an alternate strategy where they can control the risks involved as well as benefit from the new possibilities, SoMLAC is one such method. It proposes that the organizations migrate their legacy applications from local data-centers to the cloud iteratively. As during this migration process the organizations shall not only have the possibility to harden and stabilize their cloud infrastructure for future iterations, the organizations can also build competence in this area.

Although the private sector has been migrating to the cloud infrastructure but the public sector specially the government sector has been skeptical. This is because the information stored in many of the government systems is critical for its day to day functioning as well as the information may contain information of citizens which need to pass strict regulatory requirements. If the industry can help answer these basic fundamental requirements then it will not only save tax payer money but the savings can help provide even better governance.

8.2 Method results

Strategy for Migrating Legacy Applications to Cloud (SoMLAC), is based on well understood legacy migration strategy called Chicken Little [5]. During the thesis work I have also considered Cold Turkey but have found this not suitable for most projects. While the Chicken Little strategy involves iteratively upgrading a legacy system, the Cold Turkey proposes that the entire system be rewritten completely in a single iteration, which goes against the goal for finding a strategy which reuses as much as possible of the existing application architecture and design. SoMLAC, advises the use of Service Oriented Architecture, SOA. As SOA architecture helps in modularizing the Information System, thus simplifying its migration as well as systems long term maintainability.

When planning the migration of an application to the cloud, it is important to know and define the expectations both from customer’s and cloud provider’s perspective. The following checklist helps in defining the scope of migration activities along with identifying the issues and concerns. It even helps to identify who is responsible for what.

SoMLAC defines a number of different aspects which need to be considered during the three different phases, thus providing a template which helps in planning legacy system migration along with helping the decision makers plan modernization and migration of legacy applications to the cloud. SoMLAC helps the executers (project managers, architects, release managers and maintenance mangers) to plan the migration as well as identify and manage the pre-known risks
before they actually occur during the execution of the project. This has a significant impact on the acceptance as well as the profitability of the migration project.

8.3 SoMLAC at Visma

Visma Consulting has been offering one of its products to a number of Swedish counties called VSP for registering feedback of patients after they have received help at a local healthcare center such as hospital. Visma Consulting has been tasked by the Swedish counties to upgrade this system.

SoMLAC has been developed during the course of this project analysis. As a result of this analysis Visma proposed three possible alternative solutions

- Add new functionality to existing VB6 solution, with few limitations where some of the must have requirements cannot be fulfilled as well as will have a higher lifecycle maintenance cost.
- Customize a well-known CRM product, where all the must have requirements can be fulfilled but one which will entail high license costs.
- Upgrade the existing legacy VB6 solution with a modern Microsoft .NET based solution. The new solution is proposed to be modular and SOA based (Service Oriented Architecture). The solution development costs shall be high as well as there shall be risks involved but when implemented there are to be significant savings in system maintenance phase. Visma also offered to host the new solution as a SaaS solution where each county only needs to pay based on the number of users it has.

After careful analysis for few months, the Swedish counties have selected the third solution where Visma shall upgrade the legacy application to the new Microsoft ASP.NET based SOA application. Six Swedish counties have even selected the SaaS variation where they shall only be consumers and Visma is responsible for providing the modernized solution and hosting it, the counties shall pay per use of the service, while three counties shall have the solution installed locally.

Challenges faced at Visma

Although Visma Consulting has previously hosted a number of other applications for its customers as cloud solution, this project is complex as it is a pilot project, where a legacy system is to be upgraded with a possibility to host locally with some customers as well as to be hosted as a cloud solution for others.

Even though the original application is also web based, it cannot be used as a cloud solution. Current version of application does not fulfill one of the basic requirements of the cloud, multi tenancy and data segregation. In order to fulfill this requirement the application needs to be redesigned ground up. A new identity and access control service needs to be built which shall identify the users from different counties and user from each county shall only have access to the information belonging to that county.

Apart from this as the information stored in the application contains information about citizens, some fundamental questions related to data security need to be answered. The sub-contractor company to Visma Consulting which shall host the application needs to fulfill some of the legal requirements such as guarantee that all information which is stored shall be stored on servers located in Sweden.

8.4 Comparison with other research in this area

Migration of applications to the cloud has been discussed with in various different forums in recent times. There are a number of well-structured literatures available on the topic which cover various different aspects while migrating applications to the cloud. It will not be possible to cover all the
different literature which are present. In order to give a comparison of the results of this thesis with the available literature, the research articles covering the three different application layers (presentation, architecture and hardware) are considered.

The article “Legacy Applications to the Cloud” Xin et al [41] discusses a strategy called Application Migration Solution (AMS) for converting a legacy application into a web application. The motivation for the strategy among others is because of the lack of availability of legacy application code and the enormous amount of workload required for migrating the application. The concept of GUI recognition is built on the presumption that irrespective of complexity all GUI are built using basic components, and each of these component can be mapped to a corresponding HTML component. Apart from this the authors talk about an AMS server which employs multitude of programming languages such as Visual Basic, Visual C and ActiveX to identify the GUI developed for application developed in respective programming languages. Thus the strategy is to design a web GUI facade for the end user and map the user activity to the different activities in the legacy application and while doing so transfer data between the web GUI and the legacy application GUI running inside AMS server. Although this approach is innovative it lacks optimal utilization of cloud resources as well as introduces many more complexities to the application lifecycle where any change to the legacy application requires that the AMS server mapping be updated. Although this article provides a way to convert legacy application into a web application, there is a difference between a web application and a cloud application. Whereas a web application is one which is accessible over the network inside a web browser, it cannot be called a cloud based application as it does not address the cloud fundamentals such as elasticity, user identity and access control management and multi-tenancy inside environment. The approach may be relevant for some scenarios but is not general which can be adopted by all legacy application migrations to the cloud. SoMLAC is a strategy which may be applied for migration of legacy applications to the cloud, irrespective of the technology on which the legacy application are built.

The book “Migrating Legacy Applications, Challenges in Service Oriented Architecture and cloud computing environment” written by Anca et al [42] focuses on the challenges which are faced when legacy application are moved to the cloud and a SOA architecture is employed. The book covers different strategies for example reengineering of legacy application and making them cloud enabled by wrap legacy application modules and transform them into web services. This strategy helps preserve the proven functionality. The book further talks about how to bridge the gap between the SOA and RESTful architectures, this is an important aspect with respect to the future as more and more applications are not only moving to the cloud but need to be mobile enabled. This literature is an extremely important complement to this thesis, as the thesis provides an overview model SoMLAC for migration of legacy application to the cloud, which is inspired by the Chicken Little [5] strategy, while the book by Anca et al [42] focuses on how the actual migration should be realized and how the application architecture should be made.

A white paper by Cisco [43] discusses many aspects related to the application architecture changes which can gain from better utilization of hardware resources, Scale-up and Scale-out architectures. The scale-up architecture is where the application performance is improved with the availability of more hardware resources such as CPU and memory, while Scale-out architecture has to do with the increase in performance with the availability of more nodes. The article also talks about application data flow optimization between different application layers. All these aspects are important and relevant as they not only affect the application performance and stability but also affect the basic cloud price model where often the data flow within the cloud is free but in and out of the cloud is charged. The information flow between different application layers and employment of SOA can directly affect the application performance as the data transfer rates between the memory and the CPU are much higher than the data transfer rate over the switching network. This paper is a complement to SoMLAC as it helps organizations migrating applications to the cloud better understand the complexities of the cloud infrastructure and design better application architecture when making changes to the legacy applications.
9 Conclusion

9.1 Conclusion

Adopting cloud is not a project but a process. SoMLAC identifies a checklist and believes that if an organization, private or public, is planning to migrate its legacy application to the cloud, they can use it to quickly identify the areas which need focus. SoMLAC is not only intended to help the organizations to move single application to the cloud but is aimed at helping organizations to formulate a long term strategy and develop reusable components such as:

- Secure data stores
- Encryption services
- Log management
- Identity and Access control services

Thus making the transition smooth, cost effective and reliable.

All application migrations are risk prone, especially those which require significant changes to the existing application. Thus a detailed risk analysis should be made before undertaking such analysis, although SoMLAC checklist does not claim itself to be complete and comprehensive for all projects, but it is generic and should at least be considered by organizations planning and doing migration of legacy systems.

9.2 Recommendations

Cloud is not for real time applications as there are many unknown factors but at the same time it is stable enough for most of the applications used inside companies and organizations and as a result more companies are adopting it.

An organization migrating applications to the cloud need to do a significant study as to how the business can be affected by:

- Outages in cloud infrastructure
- If the information stored is compromised
- Statutory as well as legal requirements
- Identify the risks involved before beginning with the project instead of vice versa.

9.3 Future work

This thesis has had significant focus on migration of legacy system from local infrastructure to the cloud. There is a significant room for research and standardization which can be achieved in the Phase 2 “IaaS to PaaS” migration as well as Phase 3 “PaaS to SaaS”. Creating a comprehensive checklist for these requires interaction and input from teams working on different PaaS platforms as well as SaaS products. Such feedback and input has been unavailable at Visma Consulting AB and thus any future work on this can focus on these areas.
10 References


11 Appendix

11.1 Interview Template 1: “Understanding of company’s processes, project selection and selection of key individuals”

<table>
<thead>
<tr>
<th>Individual Selection Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. What is your role in the company?</td>
</tr>
<tr>
<td>2. What are the responsibilities for your role?</td>
</tr>
<tr>
<td>3. How long have you been working in the current role?</td>
</tr>
<tr>
<td>4. What other roles have you worked with?</td>
</tr>
<tr>
<td>5. Which project/s are you currently working on?</td>
</tr>
<tr>
<td>6. Which other projects have you worked in before?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Project Selection Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>7. What is the project scope and who is the customer?</td>
</tr>
<tr>
<td>8. What is the project plan?</td>
</tr>
<tr>
<td>9. Can this application be considered a legacy application?</td>
</tr>
<tr>
<td>10. Does this application deal with migration?</td>
</tr>
<tr>
<td>11. Does this application use centralized computing resources or cloud computing?</td>
</tr>
<tr>
<td>12. Do you see any possibility in the near future to use cloud computing in this application?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Previous Experience</th>
</tr>
</thead>
<tbody>
<tr>
<td>7. Has any of your previously worked project dealt with legacy application migration?</td>
</tr>
<tr>
<td>8. Has any of your previously worked project involved cloud computing?</td>
</tr>
<tr>
<td>9. What challenges did you face while working in previous projects while dealing with migration and/or cloud computing?</td>
</tr>
<tr>
<td>10. What do you think worked best in previous projects dealing with migration and/or cloud computing?</td>
</tr>
<tr>
<td>11. What experience did you gain from that migration project?</td>
</tr>
<tr>
<td>12. What recommendations do you have for any future legacy system migration and/or cloud migration project?</td>
</tr>
</tbody>
</table>

Table 7 ■ Interview Template 1

11.2 Interview Template 2: “Validation of preliminary strategy against selected company projects”

<table>
<thead>
<tr>
<th>Migration project</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. What is/was your role in the project?</td>
</tr>
<tr>
<td>2. What is/was the migration project scope?</td>
</tr>
<tr>
<td>3. What challenges do/did you face in the migration project?</td>
</tr>
<tr>
<td>4. What worked best in the migration project?</td>
</tr>
</tbody>
</table>
## 5. Have you looked at the preliminary cloud migration strategy/model?

### Review of (preliminary) SoMLAC

5. What is your opinion of the model?

6. If you were to have had it available in the beginning of the migration project, would you have used it?

7. How would it have helped you?

8. What do you think that might have/does not work?

### Suggestions for improvement of (preliminary) SoMLAC

4. Do you have any recommendations?

5. Will you use this in any future/current migration project?

6. How will you rate the model with respect to generality and reusability?

### Table 8 - Interview Template 2

11.3 Interview Template 3: “Validation of the final SoMLAC strategy”

### Migration project

1. What is/was your role in the project?

2. What is/was the project scope?

3. What challenges do/did you face in the project?

4. What worked best in the project?

### Familiarity with SoMLAC migration strategy

3. Have you looked at the final cloud migration strategy/model?

4. What is your opinion of the model?

### Addressal of concerns (preliminary SoMLAC migration strategy)

3. Did you have any concerns with the preliminary model?

4. Have your concern been addressed in the final model?

### Suggestions for improvement

2. Will you like to change something/your recommendation?

### SoMLAC reusability

4. Is the model complex or is simple to follow?

5. Will you use this in any future/current project?

6. How will you rate the model with respect to generality and reusability?

### Table 9 - Interview Template 3

11.4 System observation template

<table>
<thead>
<tr>
<th>Application Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>System environment</td>
</tr>
</tbody>
</table>

60
### Functionality

### Integrations

### Authentication mechanisms

### Data storage

### Data security mechanisms

### System users

### System use cases

### System history

**Is the system a legacy or modern?**

**Current development activities**

### Planned development activities

- **Does planned development include migration to cloud?**
  - **Strategy or model being used?**
  - **Challenges being faced while the system is being migrated to the cloud.**

- **Does the system use cloud resources?**
  - **Model or strategy employed for cloud migration.**
  - **Challenges faced when the system was migrated to the cloud.**
  - **What level of cloud migration (IaaS, PaaS or SaaS)?**

- **Does the system plan to use cloud resources?**
  - **Does the system fulfill criteria to be migrated to the cloud?**
  - **Foreseen challenges if the system was to be migrated to cloud.**

### 11.5 Interview transcripts

Thesis work has been conducted at a company. The company concerned has requested confidentiality of its client systems with respect to system design, documentation, architecture and observational analysis. Partial interview transcripts can be provided by the author upon request.

### 11.6 SoMLAC compliance checklist

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Phase 1 (Legacy To IaaS)</th>
<th>Yes</th>
<th>No</th>
<th>Comment</th>
<th>Remark (changes made to the preliminary model)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1</td>
<td><strong>Organizational Impact</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>How the organization would be harmed if:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1.1</td>
<td>The application becomes widely public and widely distributed?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1.2</td>
<td>An employee of cloud provider accessed the application and/or application data?</td>
<td></td>
<td></td>
<td></td>
<td>updated</td>
</tr>
</tbody>
</table>

Table 10 ■ System observation template
<table>
<thead>
<tr>
<th>1.1.3</th>
<th>The process or function is manipulated by an outsider?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1.4</td>
<td>The process or function failed to provide expected results?</td>
</tr>
<tr>
<td>1.1.5</td>
<td>The information/data were unexpectedly changed?</td>
</tr>
<tr>
<td>1.1.6</td>
<td>The application was to be unavailable for a period of time?</td>
</tr>
</tbody>
</table>

1.2 **Cloud service provider selection criteria**  
The cloud infrastructure service provider for the application should be able to answer the following questions.

<table>
<thead>
<tr>
<th>1.2.1</th>
<th>Where is the data stored? <em>(physical location and data center configurations)</em></th>
<th>updated</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.2.2</td>
<td>How often is the data backup taken?</td>
<td></td>
</tr>
<tr>
<td>1.2.3</td>
<td>Where is the backup data stored?</td>
<td></td>
</tr>
<tr>
<td>1.2.4</td>
<td>Who has access to the infrastructure and data?</td>
<td></td>
</tr>
<tr>
<td>1.2.4.1</td>
<td><em>What access do they have?</em></td>
<td></td>
</tr>
<tr>
<td>1.2.4.2</td>
<td><em>Access logging?</em></td>
<td></td>
</tr>
<tr>
<td>1.2.5</td>
<td>What is the Incident Response Lifecycle?</td>
<td></td>
</tr>
</tbody>
</table>
| 1.2.6 | When and who did the last Security audit?  
*Which industry standard was followed ISAE 3402/SSAE 16 (replaces SAS 70), PCI, HIPAA and ISO 27002* | updated |

1.3 **Application functional and non-functional requirements**  
A legacy application needs to fulfill following requirements before it can be migrated to the cloud. These need to be discussed and considered during the decision making process as well as during design and development.

<table>
<thead>
<tr>
<th>1.3.1</th>
<th>Application access and architectural requirements. <em>(Functional)</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.3.1.1</td>
<td>Identity and access management system for the application needs to be developed or sourced</td>
</tr>
<tr>
<td>1.3.1.2</td>
<td>Where is the data center located?</td>
</tr>
</tbody>
</table>
1.3.1.3 | Do any statutory and legal requirements need to be fulfilled?  

1.3.2 | **Application responsibility and accountability (non-functional)**

1.3.2.1 | Clearly define the responsibilities of organization and that of the cloud infrastructure service provider

1.3.2.2 | Define SLA and incident management

1.3.2.3 | Data privacy and accountability is maintained?

1.3.2.4 | Application and system logging

1.3.3 | **Availability (non-functional)**

1.3.3.1 | Are backup routines defined?

1.3.3.2 | How can the system be restored from backup?

1.3.3.3 | How long does system restore take?

1.3.3.4 | Are backup routines defined?

1.3.3.5 | Where is the backup located?

1.3.4 | **Data security (Functional)**

1.3.4.1 | Application data stored in database is encrypted and protected?

1.3.4.2 | Application accesses its data through encryption web-service?

1.3.4.3 | A secure communication protocol (HTTPS, Secure FTP) is used for communication between cloud application and clients

1.3.4.4 | Are encryption keys and/or certificates used for securing application and infrastructure stored either in local infrastructure or a key management system?

1.3.4.5 | Are virtual cloud infrastructure hard-drives are encrypted?

1.3.4.6 | Only a limited personal have access to cloud infrastructure and their activities are logged?

1.3.4.7 | Who has access to application data and logs?

1.3.5 | **Portability (non-functional)**
| 1.3.5.1 | Can existing virtual machines be migrated to cloud infrastructure? |
| 1.3.5.2 | Can virtual machines be moved within different data centers owned by the cloud infrastructure service provider? |
| 1.3.5.3 | Is the application, application data and infrastructure portable? |
| 1.3.5.4 | Can the organization retrieve the cloud image in a format which can run inside local infrastructure or inside infrastructure provided by another cloud infrastructure service provider? |

2 | Phase 2 (IaaS to PaaS) |
---|----------------------|
2.1 | Is the Identity and access management (IAM) system reusable in other applications? |
2.2 | Can the previously developed data protection mechanisms be reused between different applications? |
2.3 | Can platform service guarantee data isolation between applications? |

3 | Phase 3 (SaaS) |
---|----------------|
3.1 | Can application guarantee data isolation for different customers? |
3.2 | Which statutory and legal requirements the application need to fulfill? |
3.3 | Does the application meet statutory and legal requirements? |