The Banking Industry Underestimates Costs of Cloud Migrations

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***Abstract*—Cloud computing is a growing part of the IT industry and is seen collectively as a solution to manage data and systems effectively. In numerous areas, cloud computing is being used as the standard for deploying application areas include; banking, telecommunications, and logistics. However, migrating IT infrastructure and applications to the cloud can induce hidden and overlooked costs. This study examines the cloud migration process of ten international corporate banks, to explore and understand costs occurring during a cloud migration. We have identified that the banking industry underestimates cloud migration costs and that budgets are exceeded. The top five cost categories that are underestimated: (1) managing dependencies of applications, (2) legislation, (3) support required from other non IT departments, (4) re-architecting of applications, and (5) hiring of external contractors. Main reasons for overspending are: (1) lack of proper and rigorous business cases, (2) knowledge deficit related to cloud migrations and the corresponding IT-architecture, and (3) no clear cloud migration strategy. Cloud computing is a transformative technology which requires a rigorous approach to remain within budget and deliver the desired results.**

I. INTRODUCTION

According to [1] "every day 2.5 quintillion bytes of data are being generated and this is only increasing". Especially with other emerging technologies, such as Internet-of-Things, it is expected that amount of data will grow exponentially. These substantial amounts of data have to be governed and controlled. Cloud computing technology is identified as a solution to manage these increasing amounts of data with a scalable approach and to increase time-to-market of IT solutions [2]. Cloud computing is changing the entire information technology industry and is one of the fastest-growing technologies [3], [4]. Cloud vendors are assertive with proposing efficient cloud operating business models and claim to lower IT infrastructure costs [5]. Cloud computing services offered by Amazon Web Services (AWS) and MS Azure are developing rapidly. However, financial transparency of their business models is significantly lacking and can lead to hidden costs during cloud migrations [6], [7]. Cloud providers, such as AWS, promise effective use of cloud services and market them as pay-per-use. Due to the attractiveness of the business model proposition of AWS and MS Azure, companies do not properly analyse the decision to migrate to cloud computing, and consequently, this poses increased risks such as vendor-lock-in, and underestimated cloud migration costs [8], [9]. A literature study analyzed 53 articles and identified a clear research gap regarding costs of cloud computing and a lack of a consistent body of research for cloud economics [10], [11]. Furthermore, a research conducted by the University of Dublin demonstrated that cloud migration is an immature research field [12]. How to progress and execute cloud migration is an unanswered question for many organizations [9]. We conclude that research of cloud migration costs is still immature. There is a lack of academic research regarding this subject [10]–[12]. There is literature regarding IT costs, outsourcing, and cloud computing. However it is dispersed and in this research we integrate these subjects. We position this research as an explorative study in which we aim to identify and clarify which cost categories are underestimated during a cloud migration. This leads to the following research question:

How do the actual costs of cloud migrations compare to expected costs?

To answer the research question, we conducted a multiple case study in the banking industry. By means of structured interviews, ten different banks cost categories of cloud migration costs are elaborated. Our research reveals that banks underestimate the costs of cloud migrations. The top five cost categories that are underestimated are: managing dependencies, legislation, support required from other non IT departments, re-architecting of applications and external contractors.

This research is important for a number of reasons. First, it sheds light on how the banking industry is struggling with cloud migrations due to their complex IT-landscape and laws & regulations banks are obliged to full fill. Second, it demonstrates that it is difficult to rightly estimate budgets for complex undertakings like cloud migrations.

This paper is structured as follows. Section II discusses the related work of general costs occurring during cloud migration, as well as several cost theories. Section III elaborates the research method, data collection and analysis procedures. Section IV contains the results of this research. Section V discusses findings and Section VI concludes the paper.

II. RELATED WORK

This section discusses cloud migration costs and general cost theories. Based on literature we selected cost categories

2378-1971/20/$31.00 ©2020 IEEE
DOI 10.1109/CBI49978.2020.00039

which are relevant for cloud migration.

A. Why is cost control important?

An important obstacle for cloud adoption at large enterprises is the lack of a clear migration process [13], which is linked to a complex on-premise IT landscape [14]. A cloud migration process poses several risks: it requires planning, analysis and compatibility with the company's requirements and how availability of IT systems should be maintained at all times [9]. In two studies, hundreds of outsourcing contracts were analyzed [15], [16]. Both studies concluded that hidden costs in outsourcing contracts are the biggest problem when contract versus actual costs were compared [15], [16]. Consequences of hidden costs may have a negative impact on firm performance [17] and strategic objectives are considerably undermined and not achieved [18], [19]. If cloud migration is not addressed thoroughly, it can lead to increased and hidden costs [14]. Cloud services can be rarely used immediately as it requires customization depending on business requirements, and positioning within the architecture. A rigorous description of the enterprise architecture provides insight, enables communication among stakeholders and guides complicated change processes [20]. Costs related to these alterations are often overlooked [21], which can lead to a longer duration of the cloud migration.

B. Why do costs remain underestimated?

Hidden costs arise due to the lack of knowledge and the activities that come along with outsourcing [22]. Faced with complex business cases, decision makers struggle to estimate the actual costs of business cases and find the correct variables [17], [23]. A known problem with building business cases is usually that it is inflated and too positive. A research found strong evidence that only a few organizations could produce a justified business case for IT investments [24]. Cloud vendors pledge lower costs with their "pay-per-use" utility slogan. However fail to distinguish which components are standard and which components require re-work for which a company needs to pay for [21]. Costs are generally underestimated, due to a lack of understanding of the applications and what is required to make these work successfully [21]. With the result that these costs remain unknown to management [17]. Companies should not rely too much on the knowledge of cloud vendors but try to remain independent from the cloud vendors [6]. A stakeholder analysis identified significant disadvantages to the benefits, long term costs were volatile and to a certain extent vendor lock-in occurred due to the diffusion of control and dependency on the cloud vendor [25].

C. Cloud migration strategy

A systematic overview framed as "cloud workflow" elaborates which steps a company should take prior a cloud migration, which includes decision points [14], Fig. 1 illustrates the cloud workflow. Several factors have been identified that might impact cloud vendor selection, costs, and migration process. It has been expressed that following the cloud workflow will minimize initial migration costs and decrease the costs of managing the application after its deployment in the cloud [14]. Cloud workflow takes several steps in account for a

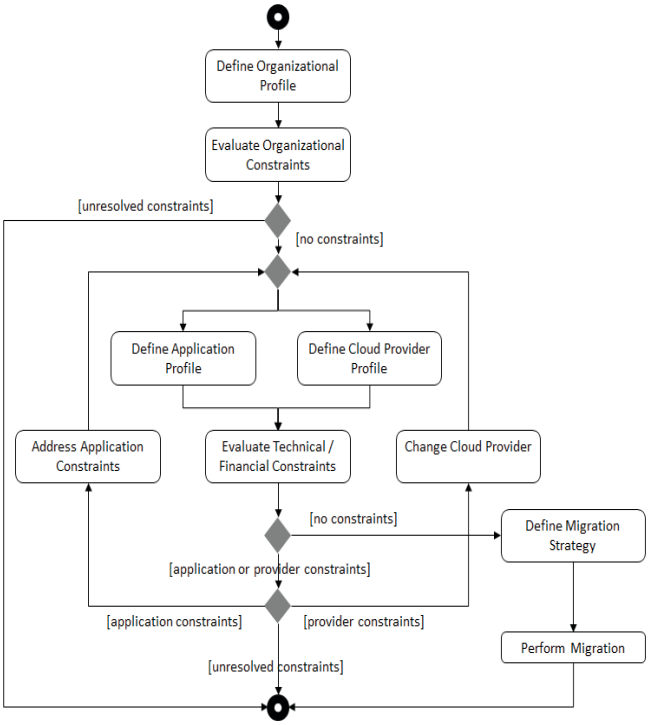

Fig. 1. Cloud workflow [15]

cloud migration, namely: cloud & migration strategy, and the execution of the cloud migration [14]. It is a clear, structured, and a relatively easy method to adopt for companies to gain insights for costs that are associated with migration and its execution process. The authors strongly advise that given the immature nature of cloud technology, multiple migration strategies should be taken into account in order to have a flexible approach, since not every application can be separated and might not benefit from the same approach.

With the current digitizing world, scaling of technology is an essential requirement. Virtualization and on-demand availability of applications accessible from every device is an essential requirement for companies, which can be achieved with cloud computing. Migrating to the cloud can yield beneficial returns if managed correctly. Cloud computing entails that IT infrastructure is flexible and this requires shared interfaces, inter-operability and security requirements [26]. Companies usually select a hybrid strategy in which the on-premise environment co-exists with the cloud solution. The migration process has several steps that can be distinguished with the stack: SaaS, PaaS, or IaaS. There are five cloud migration strategies identified [27].

1) **Rehost:** The application is running in an Infrastructure-as-a-Service (IaaS) environment. Cloud is basically approached as a data center. The benefits from cloud will not be reaped with this strategy and it is difficult to scale.

2) **Refactor:** Enables developers to re-use languages, code, and containers. As a result the application is "cloud native". This might pose framework lock-in and is not loosely coupled.
3) **Revise:** The application will be altered extensively prior to the cloud migration. The current code will be modified. This is the case for legacy applications/end of life applications which require revision. It is an expensive strategy and time consuming.
4) **Rebuild:** The existing code will not be used and is discarded. The application is usually re-build on a Platform-as-a-Service (PaaS) stack. Rebuilding ensures that capabilities and features of the cloud vendor can be taken into account to gain the full benefit of cloud.
5) **Replace:** The application is discontinued and replaced with a Software-as-a-Service (SaaS) solution. Vendor lock in of the application can be a risk, but it is an efficient solution in terms of time and costs.

D. Cloud migration costs

Cloud computing is an advanced form of IT sourcing, and management should carefully analyze the underlying costs [5], [28]. Cloud services can be rarely used immediately as it requires customization depending on business requirements, and positioning within the enterprise architecture. Costs related to these alterations are often overlooked [5]. Cloud migration is a multifaceted project with many factors involved, such as project management, digital transformation, and effective cost control. An essential obstacle for cloud adoption at large enterprises is the lack of a transparent migration process and its related costs [29]. Enterprises are struggling with cloud migrations, which is related to their complex on-premise IT landscape [14]. One of the most significant barriers for enterprises to adopt cloud computing has been the lack of visibility regarding migration processes and its costs [29]. Cloud migration is a complex project and contains several challenges for every organization. Cloud migration costs are difficult to measure and to estimate [30], [29]. There are the usual IT projects costs: (1) operational costs, (2) direct labor cost, (3) indirect (labor) costs, (4) deployment costs, and (5) systems development costs [31]. Then the question arises, how are these IT costs modelled within an organization? It depends on the size of a company, as in small organizations IT costs are accumulated and treated as a general overhead cost. While in large organizations, IT costs are charged back to departments and teams. IT costs can be further specified to tangible and intangible costs. Tangible costs can be measured in costs: direct labor, hardware, sourcing.

E. Technology Business management framework

TBM is a value-management framework and it is designed to control IT costs, aligning business & IT objectives, and to provide a standard set of categories for costs related to IT [32]. It has been identified that TBM is a strong method to achieve cost transparency and integrating IT with Finance [33]. TBM has several layers and the framework identifies the following costs pools: internal labor, external labor, outside services, hardware and software. It can be applied enterprise wide to create value for departments, increase collaboration and understand how value can be derived from IT spending [34].

III. Research method

A. Multiple case study research

The banking industry is selected due to its long history with IT systems, and was one of the first industries to adopt IT for daily operations. Furthermore, banks do not actually have a physical product, but have digital products with a high dependency on IT systems, hence it creates an interesting research field. Initially, the first months of this study were dedicated to research to what extent corporate banks are actually involved in cloud computing. Several banks indicated that cloud computing was still a subject they considered, and thus could not participate. Banks who agreed to participate, had strict rules regarding this research. As contribution was only possible if quantitative and financial data were excluded of this research and participation was guaranteed anonymously. Furthermore, databases, descriptive or structured data-sets regarding cloud migration costs were not publicly available during the time of this research. Profit and loss statements of banks for IT related costs are generally accumulated as one general cost category and not specified per cost type. As a consequence, it is not possible to perform quantitative research. Several banks were approached by means of a snowballing approach [35]. Ultimately, ten banks agreed to participate in this research. Objective of this research is to obtain a deeper understanding of the delta between actual and budgeted cost categories for cloud migrations. A case study approach for cloud migration was conducted and concluded that a case study is an effective method to investigate cloud migrations [25]. To conclude, due to the nature of our research problem and its explorative character, a case study design has the best fit.

B. Data collection method

Data is collected by means of structured interviews. These interviews are conducted confidentially and the research output and analysis are formulated in such a manner that the banks and interviewees who contributed are not traceable. This was a prerequisite for the banks to participate. Several banks had to confirm with their compliance department first, in order to approve participation for this research as sensitive information is shared. Due to this reason, we disclose only limited information about the background of the banks and interviewees. To include a bank in this research we checked if the bank was undertaking a cloud migration. Then we requested and selected a person within the bank, to participate for the interviews. This person should be knowledgeable about cloud and migration strategy as well as the financial aspects of cloud migrations. It was crucial for us to find the right participants. Ultimately, to conduct the interviews several persons per bank contributed since it was a prerequisite to have extensive knowledge about cloud migrations. Per bank we

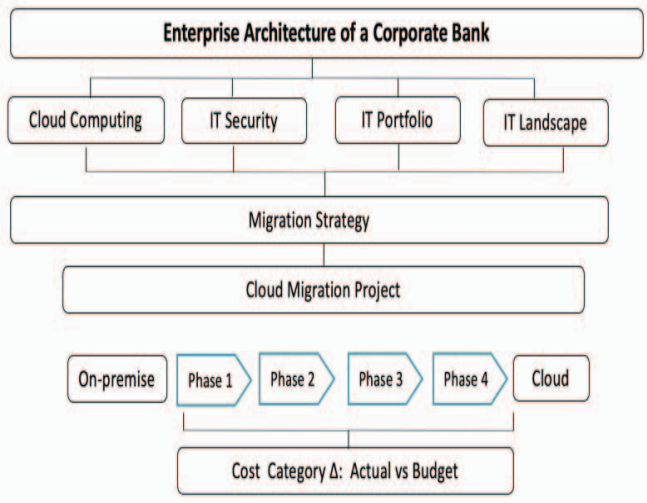

Fig. 2. Conceptual model

analyzed their cloud migration based on the follow categories: cloud & migrations strategy, internal & external labor, internal & external services, legislation, and software.

Specifically for the interviews we created an anonymous Skype account. This ensured and enhanced the privacy aspect of this research. The interviews were recorded during the interview, and the interviewees name and the bank was not mentioned during the recording. Using Skype offered another advantage namely, screen sharing. The interviewees were able to see their answers during the interview. The researcher was typing simultaneously, and the interviewee could correct the output produced immediately. Once the interview was conducted, the researcher summarized the answers and checked if the interviewee had any additions or changes. Table I contains characteristics of the banks and the interviewees. The unit of analysis of this research is a specific cloud migration project in each of the case study organizations and is elaborated in the subsection conceptual model. Interviewees were asked to keep a specific cloud migration in mind when answering questions.

C. Conceptual model

This research focuses at costs of cloud migrations. Cloud migrations have a clear process namely, starting from on-premise to the target environment: cloud. Costs incurred during cloud migrations involve many elements, such as the process itself, the organization, and the people. Hidden costs are defined in literature as:

- Differences between the expected and actual costs [17].
- Un-anticipated costs of implementation [18] [19].
- Non-obvious costs of IT, which in fact may appear in another department or function as a result of computerization [36].

For this research we selected the following definition namely, differences between the expected and actual costs [17]. Fig. 2 illustrates the conceptual model of this research.

D. Cost categories

To define clear cost categories and to generalize the outcomes, we have formulated nine cost categories specifically for a cloud migration based on academic literature as illustrated in Table II. These cost categories have been pre-tested and peer reviewed, prior to the interviews. We have selected three cloud migration experts from the banking industry that are responsible for cloud migration execution and are knowledgeable about costs (budget vs actual) that occur. The results of this peer review enabled us to scrutinize the cost categories to its essence. "Hidden costs" are analyzed by comparing the budget required for that specific migration versus the actual cost.

IV. Results

A. Cloud characteristics banks

Table III demonstrates that most banks selected a public cloud first strategy. This entails that banks, decided to migrate their workloads to the public cloud when feasible, and backed by a positive business case. In most cases, banks keep their on-premise environment active, in case legislation, data sensitivity, or a negative business case prevents migrating a specific workload to the public cloud. Bank 1 is an exception since a private cloud solution is preferred over the public cloud. This bank already invested heavily in private cloud eight years ago during a time, that public cloud was not mature yet to meet their requirements. Another exception is Bank 6, as this bank started its cloud journey with a public cloud first strategy. Later on this was revoked and this bank currently follows a hybrid cloud strategy namely: private and public cloud. The reason for terminating the public cloud first strategy, originated from the legacy applications and their core banking systems which run on mainframe systems. During their internal strategy sessions, it became clear that if legacy applications would be migrated, it required heavily re-factoring and it would take several years to prepare these legacy applications for cloud migration. It was not a realistic business case as it would require the full capacity in terms of time, budget and personnel. Bank 9 is quite critical and vocal concerning cloud computing and does not see yet how cloud can continuously deliver business value. For this bank, public cloud is only applied in case of specific business cases such as creating a new service and when additional capacity is required. Furthermore, this bank preferred not to be depended on external partners regarding their critical digital infrastructure.

Table IV contains the cloud migration strategy per bank. Bank 1 has no migration strategy yet. Bank 5 has a clear migration strategy: re-architect and with this strategy, applications will end up as high in the stack namely, Software-as-a-service (SaaS). With a SaaS solution, benefits from the public cloud will be utilized to a maximum.

Table V illustrates the main cloud vendors per bank. All banks have one or two main vendors with bank 3 as an exception. This bank, adopted a multi-cloud vendor strategy: AWS, MS Azure, and Google cloud. The reason for a multi-cloud strategy is to fulfill requirements of the business and

TABLE I
CHARACTERISTICS OF THE BANKS AND THE INTERVIEWEES PER BANK

Bank	Role interviewee	Number of years working experience interviewees	Total Assets Bank
1	Cloud Enterprise Architect	24 years	Between 500-1000 billion
2	Chief Information Officer	31 years	Between 500-1000 billion
3	Head of Digital Strategy Transformation	20 years	More than 1 trillion
4	Cloud Manager	22 years	Between 100-500 billion
5	Cloud Manager	22 years	Between 500-1000 billion
6	Cloud Enterprise Architect	8 years	Less than 100 billion
7	Cloud Enterprise Architect	29 years	Between 100-500 billion
8	Chief Information Officer	30 years	Less than 100 billion
9	Cloud Manager	17 years	Between 100-500 billion
10	Enterprise Architect	38 years	Between 100-500 billion

elevate the vendors' capabilities. Each cloud vendor has a different purpose for this bank; AWS is mainly used for application hosting, MS Azure for geographical spread and presence and Google Cloud for data analytics purposes. Bank 9 consciously selected a sole cloud provider, in order to enable full integration and inter-operability without having to manage the complexity of a multiple cloud vendor strategy.

B. Cost categories

In this section we discuss the defined nine cost categories (actual vs budget) and provide direct quotes from the interviewees to explain and highlight how the actual costs relate to the budgets. Furthermore, we discuss why cost overruns occur. Table VI contains the number of banks that demonstrated a cost overrun per cost category.

Managing dependencies.

Managing dependencies entails that if application A is migrated to the cloud, and during migration it appears that application A has dependencies with application B. To solve this, it can be decided that application B should also be migrated, or that even migration of application A should be reversed. Managing dependencies between applications is the largest bottleneck for banks during cloud migration. Eight out of ten banks spent more than budgeted for managing dependencies on applications during cloud migrations. One of the interviewees explained: *"We have many isolated systems and we are not aware of the full capabilities and functionalities of our current landscape and the impact of migrations of certain applications yet, as we are still struggling with our on-premise environment*". Another interviewee commented: *"Public cloud initially starts on-premise and all your connections and dependencies are on-premise and to decompose them for the purpose of migration is a more complicated process than expected"*. Four banks explained that decomposing the applications and its components posed to be difficult during the migration. One bank clearly admitted that overspending occurred due to a lack of knowledge of their on-premise environment. This bank clearly does not control and understand their IT landscape. It was also identified that this bank does not fully comprehend the purpose and capabilities of their applications. This was underlined: *"We had to decompose some applications due to dependencies. Cloud adoption in practice is much slower than expected due these kind of complexities"*. Another bank identified t hat changing business requirements during migration impacts managing dependencies as well.

Legislation.

Since banks bring sensitive and personal information to the cloud, there are laws and regulations that banks need to follow in order to safeguard aspects such as security and privacy. Due to the crash of 2008, the banking industry is one of the heaviest regulated industries on a global stage. The second underestimated cost category is legislation, as seven out of ten banks had an overspend compared to budget. This is clearly a topic that is keeping all banks occupied as regulations like data privacy evolve over time and are not set in stone. Several banks indicated that current processes of the regulators are strenuous. An interviewee explained: "*When we went live with a certain application in the cloud, there was not yet an European regulation regarding public cloud computing. There was nothing that we could rely on and we had to inquire every local regulator for approval regarding data storage and privacy of our customers"*. Also differences in requirements per region make it difficult for banks to manage this process on a global level, since most banks in this study have a worldwide presence. Legislation on overarching levels such as the European Union lacks and therefore every country has its own set of rules to a certain extent. *"Regulatory requirements are changing and evolving, this required more attention than expected. Regulators require more insights and more reporting as time goes by"*. Another bank commented *"Regulators require evidence and are difficult to manage. Costs associated with audits and regulations are higher than expected"*. Banks struggle with the fact that regulations change, requirements are not fully clear, and it is not clear what to expect in terms of reporting and auditing. This even resulted in one bank to clearly selecting a multi-cloud strategy (on-premise, private, and public cloud) in order to adapt when new requirements regarding legislation arise. According to this bank, legislation is lagging behind and there is no clear jurisprudence yet regarding cloud computing. It is expected by the banks that the

TABLE II
COST CATEGORIES

Cost category	Description	Literature
Managing dependencies	Costs associated with dependencies between applications. E.g., application A is migrated to the cloud and during migration it appears that application A has dependencies with application B. To solve this, it can be decided that application B should also be migrated or that even the migration of application A should be reversed.	[13] [11] [37] [23] [29]
Legislation	Costs that are related to certain rules and regulations that organizations have to follow	[27] [13] [38] [29]
Support other departments	Support costs from departments that are indirectly related to cloud migration such as risk, compliance and security departments	[19] [13] [30] [29]
Re-architect	Costs of fundamental changes that are made, such as changing the code of an application.	[13] [39] [40] [29]
External contractors	Costs of developers and consultants that are hired for their specific skill for a limited time.	[29] [40] [32] [13]
Internal resources	Costs that refer to the organizations internal staff. Internal resources are a key element in building the knowledge and gaining experience with cloud migrations.	[13] [32] [29] [30]
Cloud training	Costs of training internal personnel. Training is a prerequisite as it requires a different way of building and managing applications compared to on-premise.	[8] [29] [13]
Cloud migration core team	Costs of a cloud migration core team. Such a team is an essential part of sustaining the knowledge and offering support to teams. Cloud migration is part of an enterprise wide project and it should not be treated as an isolated project. It requires that several teams across the organization work together in adopting cloud computing. A cloud migration team can facilitate this process and act as an internal consulting team enterprise wide.	[13] [29] [8] [10] [29]
Third party services	Costs of contracting services. These costs are different from external contractors, as a third party manages a process end to end, for example AWS can provide the cloud environment but can also actually implement and facilitate the transformation to cloud.	[32] [37] [19]

costs for legislation will increase as it was mentioned: *"Regulations regarding data privacy and storage at cloud vendors will have a big impact on cloud computing"*. Additionally, difficulties were experienced: *"It takes a huge effort to be compliant and we have a knowledge gap. It requires a new way of working and how to report to these legislation entities"*. Furthermore, contract management with the cloud provider, proved to be increasingly complex as it was mentioned by one bank *"Setting up a contract with the public cloud provider was much more complicated than expected. Initially, we did not receive clear answers about how the data is stored, which data is stored and the metadata governance. To figure out all these questions took us quite some effort, money and and time"*.

Support from other departments.

Cloud migration is not only a topic for the IT department. Support is required from other departments on subjects such as risk, compliance, and security departments. Support required from other departments during cloud migrations is an underestimated cost category that caused overspending at five banks. Elements such as risk and security required more support than expected. Cloud computing challenges organizations as it requires a different way of working. Security may be a well-known area when managed on-premise. However, cloud computing poses new challenges with regard to security. This was mentioned during one of the interviews: *"Business-IT alignment is causing slower migration. During migration the business required enhanced security, which was not covered in the business case"*. With cloud computing, data is stored externally at cloud providers. One bank mentioned that their risk department even slowed down the adoption of cloud computing due to a lack of knowledge and resources to support the cloud teams at their request from a risk perspective. *"We experienced a very slow cloud adoption from people in the organization. The business should be involved early in the construction of the business case to mitigate this risk as much as possible"*. Another bank did not even consider support from other departments and had no budget allocated. One bank had no idea if a budget overrun occurred, and their requests were fulfilled on an ad-hoc basis. Only three banks were in line with budget. These banks build and invested in relationships with the supporting departments, and it is clear that this investment in terms of relationships increased agility and effectiveness of the cloud migration.

Re-architect.

With re-architecting fundamental changes are made, such as changing the code of an application. Five out of ten banks spend more on re-architecting of applications during migration. Two banks did not budget yet to re-architect, but were realistic about the possibility that it will occur, as legacy application were not yet During cloud migration at one bank it became clear that a certain solution was not offered by the cloud vendor and in order to fulfill business requirements, the bank had to re-architect. It seems that during cloud migration, banks are not fully aligned yet with the possibilities offered by the cloud vendor: *"We had some complex migrations and these issues that occurred are very time consuming"*. Two banks struggled with end of life applications and it became clear that it was necessary to re-architect the applications. Complexity and underestimation of the cloud migration process were given as reasons for overspending. It was identified by a bank that re-architecting is a risky business: *"The biggest danger for cloud migration is the difficulty to change IT. For a long time IT didn't change, and then at a sudden moment we approach it with a big bang. For continuity reasons, renewal of applications should be approached on a continuity basis and not with a big bang. That is a very risky operation*". Outdated applications also required re-architecting and the

TABLE III
PRIMARY CLOUD STRATEGY PER BANK

Bank	Cloud strategy		
	On-premise	Private	Public
1		X	
2			X
3			X
4			X
5			X
6		X	X
7			X
8			X
9	X		X
10			X

TABLE IV
CLOUD MIGRATION STRATEGY PER BANK

Bank	Migration strategy				
	Rehost	Refactor	Revise	Rebuild	Replace
1					
2	X	X	X	X	X
3	X (pilot)				
4	X	X	X	X	X
5		X			
6		X			
7	X	X	X	X	X
8	X	X	X	X	X
9					X
10	X (pilot)				

intended solution did not work, as it was emphasized: *"The solution was not suitable and the application could not work. Therefore we had to re-architect the application service"*. Furthermore, certain components of the cloud migration were not provided as one bank commented: *"Certain components could not be guaranteed by the cloud provider and we had to re-architect during the migration to fulfil our own internal requirements to make sure it was secure"*. Banks experienced difficulties in not knowing exactly what to expect during a cloud migration: *"It is difficult to find the right balance. We knew we had to re-architect, but what we come up with in theory does not necessarily work in practice"*. Certain applications were identified as critical and this also caused re-architecting: *"Architecture became involved to adopt services, which allowed portability between cloud providers: this was not taken into scope from the beginning. The migration of critical applications to the cloud was quite complex from an IT security perspective and it required more work. We also needed an exit strategy for the critical applications. This is a requirement from regulators and required extra work"*.

External contractors.

External contractors are software developers and consultants who are hired for a specific capability that the company does not have in-house. External contractors' reliance and knowledge management for cloud migration purposes is underestimated as five out of ten banks spend more compared to budget. None of the banks spend less than budget. Banks had overspend due to several reasons, as required knowledge for cloud migration was internally not available. Two banks have outsourced their complete IT infrastructure to an external vendor. Migrating to public cloud in construction with an outsourced IT infrastructure did not do any favor and increased the dependency for external vendors, which is a risk itself. Hiring external contractors should always be a trade-off between knowledge preservation in-house and managing the cloud migration. From a project management perspective, certain parts of migration at one bank was not well prepared beforehand, and the project had an overrun. Another bank had to support a changing business requirement and in order to fulfill this request, an external contractor had to be hired for specific knowledge: *"We are still in the learning curve and we don't have the required knowledge yet. So we had to spend more on external contractors for cloud migration purposes"*. Even though one bank is very keen on sustaining the knowledge internally, they still had to spend on external contractors regarding security and risk: *"Security from on premise to the cloud could not be guaranteed by the cloud vendor, we had to extend our firewall capacity and this causes extra costs that were not known prior to migration"*. Overspending on external contractors is an indication how the process of migration is actually progressing. It displays which areas lack the required knowledge to manage the cloud migration internally. Furthermore it was mentioned: *"I can imagine that trained staff leaves the company if they perceive the progress is too slow. This is a real risk and companies need to work on retention plans. Our bank worked for many years with external contractors, they all left and the current internal employees are recently hired. We have very limited knowledge of the on-premise IT infrastructure and this is a continuous struggle for us"*.

Internal resources.

Internal resources are a key element in building knowledge and gaining experience with cloud migrations. Internal resources are referred to internal personnel at the bank. Four out of ten banks spent more regarding internal resources compared to budget. In all these four cases, a budget was allocated for internal resources, yet overspend occurred. In all these cases this was due to the fact that budgets were too optimistic, and because of a knowledge gap regarding cloud migration. This gap was not known prior to migration and is related to building a feasible business case: We had ongoing discussions, different views of public versus private cloud, maintain versus manage, with no clear financial figures for the business cases (on-premise vs cloud. Another bank commented: "I believe we hardly ever check the original business case versus actual materialization of the business case. Most business cases are approved based on business benefits that are not measured". Since cloud computing is a relatively new technology there is a steep learning curve, which is reflected in the overspending compared to budget: "It requires a huge change in mindset and way of working to realize this cloud computing shift".

TABLE V
MAIN CLOUD VENDORS PER BANK

Bank	Cloud vendor		
	AWS	MS Azure	Google
1		X	
2	X	X	
3	X	X	X
4	X	X	
5	X	X	
6	X	X	
7	X		
8		X	
9		X	
10	X	X	

One bank spent less than budgeted, because it runs behind schedule with their cloud migration, which in the end will lead to higher costs than budgeted.

Cloud training.

Cloud training for internal personnel is a prerequisite as cloud computing requires a different approach of managing applications & IT landscape compared to on-premise environment. Four out of ten banks spent more money than initially budgeted on cloud training. At one bank, there was significantly less money spent on cloud education compared to the available budget. The reason for this was a general lack of interest from the internal personnel for cloud training's, and it was not promoted by the bank. Another bank has spent more than expected: *"We did not have the full picture and underestimated what was required to certify our personnel"*. At one bank, cloud training had a positive take-off within the organization, and whilst doing the training, their personnel recognized that the knowledge gap was even more significant than anticipated. While some banks carefully plan the required budgets upfront together with their HR departments, other banks have a limited budget for training. Indirectly, the extent of the budget that is spent on cloud training demonstrates the pace of the cloud adoption progress.

Cloud migration core team.

Forming a cloud migration team is an essential part of sustaining knowledge and offering enterprise wide support as cloud is a transformative technology. Banks have overarching cloud teams, in which cloud migration is part of the team's objectives and focus. This core team develops the helicopter view for cloud migration execution and supports other teams that are in the process of cloud migration and adoption. Three out of ten banks overspend their budgets regarding constructing and setting up cloud migration teams. The complexity of the cloud migration and general adoption of cloud computing is the main cause for overspending, as more personnel was required then initially expected. *"The level of experience within the industry is very low regarding cloud computing, the chance of hitting unexpected costs is high, because we are experiencing it for the first time"*. Another bank mentioned: *"When we started we thought we would need a certain amount of resources. However, we miscalculated because we were too positive. We have a knowledge gap and cloud is the main reason for this"*.

TABLE VI
NUMBER OF BANKS WITH COST OVERRUN PER COST CATEGORY

Cost category	Number of banks with cost overrun
Managing dependencies	8
Legislation	7
Support from other departments	5
Re-architect	5
External contractors	5
Internal resources	4
Cloud training	4
Cloud migration core team	3
Third party services	2

Third party services.

Third party services is different from external contractors, as third party services manage a process end to end. For example, AWS may not only provide the cloud storage but also executes parts of a migration project. Two banks spend more than expected on third party services due to a lack of knowledge of cloud migration and its complexity. Two banks were in line with budget projections. Several banks commented that third party services will increase once the legacy applications will be migrated: *"We don't dare to touch legacy applications"*. One of the banks commented *"It is too expensive to migrate our mainframe applications, we don't have the capacity nor the budget to invest heavily in migrating mainframe applications. The return on investment was not positive. Furthermore, we had to do major investments in our infrastructure and our network"*. Another bank had problems with their general IT outsourcing partner, and therefore had to hire third party services: *"Our internal IT is very limited because we have outsourced our IT infrastructure to a great extent. Our vendor which fully controls our our IT infrastructure end to end, refused to work with us on public cloud, since this vendor manages our on-premise environment. Cloud migration was not of interest to them. Therefore we had to seek other vendors for public cloud"*.

Table VII summarizes the results per bank. From Table VII we learn that Bank 5 underestimated seven and Bank 10 six out of nine cost categories. Bank 5 was the furthest in its cloud migration. This also explains the large cost overruns. As a migration project evolves, it is more likely that costs will increase, as complexity increases when more and more applications will be migrated to the cloud. In general, all banks included in this research started to migrate relative low impact applications to the cloud. Legacy applications were scheduled once experience was gained with the relative low impact applications. Bank 10 is an outlier, as this bank, was more or less completely managed for many years mainly by external contractors. This caused several problems at different levels, such as a knowledge gap related to their IT landscape and underestimation of cloud complexity.

TABLE VII
ACTUAL COSTS COMPARED TO BUDGET PER BANK PER COST CATEGORY (MORE = ACTUAL COSTS ARE HIGHER THAN BUDGET. EQUAL = ACTUAL COSTS ARE EQUAL TO BUDGET. LESS = ACTUAL COSTS ARE LOWER THAN BUDGET. N/A = COST CATEGORY IS NOT APPLICABLE)

Bank	Managing dependencies	Legislation	Support other departm.	Re-architect	External contractors	Internal resources	Cloud training	Cloud core team	Third party services
1	More	Equal	More	Equal	Equal	Less	Less	n/a	More
2	More	More	Equal	Equal	Equal	Less	More	Equal	n/a
3	n/a	n/a	Equal	n/a	More	Less	Equal	Equal	More
4	Equal	More	More	More	More	Equal	Equal	More	Equal
5	More	Equal	More	More	More	More	More	More	n/a
6	More	More	More	More	Equal	Equal	More	Equal	Equal
7	More	More	n/a	More	n/a	Equal	Equal	n/a	n/a
8	More	More	More	More	Equal	More	Equal	More	n/a
9	More	More	Equal	n/a	More	More	Equal	Equal	Equal
10	More	More	More	n/a	More	More	More	Equal	n/a

V. DISCUSSION

Analysis of the defined cost categories of cloud migration projects at 10 corporate banks reveals a number of interesting insights. This research identified that the banking industry underestimates cloud migration costs and that budgets are exceeded. In total eight of the ten banks spend more than budget regarding managing dependencies of applications. This is in line with earlier research that dependency issues are often underestimated [41]. Even AWS, one of the market leaders in cloud computing, strongly advises that dependencies of applications should be mapped and analyzed prior to cloud migration [37]. Overspend regarding managing dependencies of applications demonstrates the extent of in-depth knowledge banks hold regarding their on-premise applications.

For the category legislation more was spend than budget at seven banks. Banking industry is one of the highest regulated industries on a global stage and a recent study signifies that even though cloud computing offers certain benefits, it does increase legal complexity exponentially [38], [42]. Due to clouds dynamic nature and data is dispersed globally, it is inherently difficult to comply with regulators [42]. Data storage, outsourcing data of customers and privacy sensitivity are underestimated problems. Moreover, legislation on overarching levels such as the European Union is lacking and therefore every country has to a certain extent, its own set of rules. Cloud migration costs are underestimated in the banking industry. One of the main reasons is the lack of proper and balanced business cases. Cloud computing is a new technology and cannot be approached as a typical IT project, because it has unique features. Most banks do not manage cloud migration costs separately, which does not contribute to understanding and predicting cloud migration costs. Also, banks severely underestimate managing dependencies of applications during a cloud migration. Academic literature provides several cost methods and strategies to prevent underestimation of costs to a certain extent. Approaching cloud migrations with cost theories provides insight, and may help to formulate early requirements as part of the business case. Academic literature advocates for a clear cloud and migration strategy [14]. Most banks have a mix of several migration strategies, only two banks had a clear process of selecting and following their migration strategy, other banks opted for a mix of the five migration strategies. Two banks which have a clear migration strategy, are testing the selected migration strategy with a pilot phase, to see what actually works. In this pilot phase, applications will be migrated to the cloud and tested with several migration strategies to see how it works and evolves in practice. Based on the results of this migration pilot, the migration strategy is selected. Thus, it can be concluded that most of the banks don't follow academic literature in constructing a clear migration strategy.

This study has a number of limitations. The banking industry is a rather closed environment, especially in terms on how projects are managed and costs that occur for strategic projects, such as cloud migration. Data collection of financial figures was not possible because this type of data is treated as highly confidential and cannot be made publicly available. For this case study we had to rely on the answers of interviewees. A significant amount of time and effort was put in to ensure that the correct person within the bank was selected. Secondly, in answering the questions the interviewees might have had different connotations with cloud migrations. Therefore, we explained to the interviewees to keep a certain cloud migration project in mind when answering the questions.

VI. CONCLUSION

This research identified that cloud migration costs are underestimated in the banking industry. This research has a significant contribution because this type of detailed and precisely constructed information related to cloud migration costs is not easily accessible, especially not in the banking industry. This research created direct insight in the cloud migration journey of ten corporate banks and provides a direct benchmark for banks to compare their own cloud computing journey with other banks. Practitioners learn how cloud migration strategies are decided and formulated, and why and under which circumstances cost overruns occur. The reason for this, is that all banks in this research still have to migrate most of their legacy applications to the cloud. For future research, it is interesting how banks approach the cloud migration of legacy applications. Banks that participated in this research

expected that migration costs will increase further and will become more volatile.

ACKNOWLEDGMENTS

The author would like to thank Joris Hulstijn, Sandor Welfing, Niels Zegveld, Erik Jongsma, Manlio D'Alessandro, and Henk van Driel for their guidance and support during this research. Furthermore, contribution of the 10 corporate banks, without their invaluable support this research would not have been possible. You have given me your trust, time, support and true insights in the process of cloud migrations, thank you.

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