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Cost Factors that Influence Ownership of Mainframe or Cloud-Based Data Center Environments

CAPSTONE REPORT

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Abstract

This annotated bibliography focuses on organizations considering the move from mainframe data center environments to cloud-based alternatives and the true total cost of ownership of the latter solution. Literature published from 2010 to 2014 is included to help executives clarify evaluations of mainframe versus cloud-based solutions by comparing cost differential and potential advantages/disadvantages of the environments. Ultimately, the intent is to understand whether to stay with existing mainframe architectures or move to cloud-based environments.

Keywords: mainframe, cloud, cloud computing, data centers, price, cheaper alternative, migration, and modernization

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Introduction to the Annotated Bibliography

Problem

Organizations considering the move from mainframe hardware in a data center environment to a cloud-based alternative must consider the true total cost of ownership. The mainframe is defined as a computing method that is well integrated into today's business environments and handles data processing requirements that are important to mission critical applications for such organizations as banking, healthcare, government and several others (Brearley & Taylor, 2013). Saran (2014) states, "[t]oday, around 80% of the world's corporate data is [still] managed by mainframes" (p. 16). Within the last few years there have been multiple technological advancements in this computing paradigm, some of which proclaim to reduce overall operating costs for data centers. The most recognized advantage to the mainframe platform is the cost effectiveness of the mainframes' massive input or output (I/O) capabilities, or communication that takes place between the mainframe and external devices such as printers or tape drives (Enderle, 2014). Furthermore, Greengard (2011) presents another benefit of continuing with the mainframe, "...users can substantially reduce site-licensing costs and save on cooling and energy expenses" (p. 1). Enderle (2014) also notes that a deterrent in moving away from an established mainframe solution is the large amount of software that does not migrate well to other architectures (para. 6).

Mainframe disadvantages. Despite the stability and nearly-unbreakable platform for processing large amounts of company data, mainframe environments still have disadvantages. The biggest disadvantage is the increasing problem of the technical gap or dearth of skilled workforce with knowledge in the development and programming tasks of mainframes. The problem is that the group that possesses this knowledge is largely composed of individuals who

are reaching the age of retirement, and organizations are offering limited training options to backfill these positions. This dilemma also includes universities not educating students in these skills, which greatly adds to the shortcomings of the mainframe (Brearly & Taylor, 2013). Another disadvantage to the mainframe is best surmised by Niccolai (2013): "... it's a costly system for which [International Business Machines] IBM needs to justify customers' continued investment" (para. 2).

This study focuses on the differences in costs that might justify a move from data centers housing mainframes to a cloud-computing model. A usable definition of a data center is a facility that contains electronic equipment that is used to process, store, and transmit digital information. The facility itself is either free-standing or contained within a larger structure that controls the environmental conditions of the equipment of the data center (Energy efficiency for data center buildings, 2014).

The cloud as an alternative. One potential alternative to data centers is to move to a cloud computing model and divert off the mainframe. The cloud takes on many different identifying characteristics and a plethora of definitions exist for this computing process; for the purpose of this study cloud computing, "...is defined as all the storage and processes that are performed on servers and are accessed through the internet rather than from computer" stated by Dogra (2012, para. 1). Some benefits of cloud solutions include unlimited scalability features, the provision of global access to computing services, and the elimination of the need to buy private infrastructure such as the mainframe (Otey, 2011, p. 4).

Cloud benefits. The reported cost differential between a mainframe solution and a cloud-based solution is significant. "It's estimated that moving these applications off the mainframe can reduce operating costs by around 60–70%, and using the cloud can go further, garnering

huge cost savings” indicated by McGill (2012, para. 6). Included in this suggested operating cost reduction, McGill (2012) also mentions that, “...many critical legacy IT applications within public sector organizations sit on mainframes, which come with consistent annual maintenance and expanding upgrade fees” (para. 2). Another documented cost savings to be gained from cloud-based services is lower maintenance costs when applications reside in the cloud because the support expense of ensuring that the applications run properly are removed (Yoo, 2011, p. 409).

The decision of whether to stay with a mainframe solution or move to the cloud is complicated by the fact that mainframe computing makes sense for a lot of organizations because it is powerful, robust, and able to handle millions of transactions every second, but this type of dependability does not come without associated disadvantages – such as cumbersome hardware to maintain and an aging workforce (“Managing mainframe costs,” 2013, p. 1). The alternative of a cloud-based solution is appealing, mainly due to the reported reduction in both annual operating costs and technology infrastructure expenditures (Dogra, 2012; McGill, 2012), but cloud computing offers other reported benefits as well. The scalability of a cloud-based infrastructure which provides organizations with greater flexibility is documented as being a key customer benefit. Another benefit is the ability to save data in a different location other than laptops or desktops which helps protect against certain types of security and privacy threats and acts as a remote backup system (Yoo, 2011, p. 412).

Cloud disadvantages. The advancement in technology represented by the cloud is gaining momentum with its aspect of pushing companies’ workloads from their own data centers into the public domain, or into “the cloud”. It is not an easy endeavor to just start the migration to cloud data centers because companies already have substantial financial investments in their

current mainframe data centers. This is not the only dilemma companies face; as mentioned by Brearley and Taylor (2013), "...the shift is pretty tough as it is expensive and takes a long time to implement and integrate. Even then, there is [still] a heavy risk..." (p. 33) of not having all necessary components implemented correctly in this new environment. Another disadvantage presented by Bishnoi and Khatri (2014) is, "[c]loud computing is impossible if you cannot connect it with internet.... if you don't have an internet connection you cannot access anything, even your documents.... A dead internet connection means no work and in areas where the internet connection is few or inherently unreliable this could be a deal breaker" (p. 639).

Mainframe versus cloud. As a consequence of the disadvantages and risks posed by both mainframe and cloud solutions, companies are faced with the following questions: Do they place faith in the reported benefits of cloud-based solutions by gravitating to the latest technologies, with the need to potentially allocate even more funds to pay for these new endeavors? Or, do they continue with their legacy mainframe solutions for which funds have already been applied? One complicating factor in deciding which course of action to pursue is the fact that, according to Saran (2014), "...the mainframe has kept up with shifts in computing paradigms and application systems" (p. 17). With the continual innovation of mainframe technology, the move to a cloud-based solution cannot be justified purely based upon arguments of technical superiority.

Migration challenges. Research is also provided that examines the inherent challenges in moving from a mainframe to a cloud-based solution. According to McGill (2012), the processes required to make such a move are complicated and result in a time consuming endeavor because, "[t]he migration of all applications from the mainframe can take between nine months to as many as three years" (para. 13). Not only does this type of migration require a time commitment,

it is also recommended by Lawal and Folorunso (2013) that a rigorous seven step migration process be followed because, “[m]igrating applications to the cloud is not an easy task” (p. 24). The seven step procedure consists of assessing, isolating, mapping, re-architecting, augmenting, testing, and optimizing each individual identified application that is going to be moved to ensure that the migration is robust and comprehensive (p. 24).

Another challenge with which corporations have to contend according to Rajan and Shanmugapriyaa (2012) is, “[t]he applications with low I/O [Input/Output] performance and tolerance for low downtime are suitable residents in cloud” (p. 44). This is a problem because migration plans that are moving critical mainframe applications to the cloud may find that this new platform is unmatched with the mainframe’s I/O capabilities and thus applications with high I/O performance are not suitable for migration. Ultimately, as noted by Enderle (2014) and Brearley and Taylor (2013) the challenge to ensure that the large amount of software that resides on a mainframe is migrated and configured correctly in a cloud environment poses a heavy risk to the organization that embarks upon this type of architecture change.

The research presented in this study is intended to help clarify the comparison of mainframe versus cloud-based solutions; as Greengard (2011) notes, “...IT executives have found themselves sorting through a dizzying array of choices about technologies, systems and tools” (p. 1).

Purpose

The objective of the purpose statement is best elucidated by Creswell (2014), who indicates that it, “...sets the objectives, the intent, or the major idea of the proposal or a study” (p. 124). With this definition, the purpose of this annotated bibliography is to present literature

that helps inform the analyses of organizational decision makers who are tasked with determining whether to stay with existing mainframe architectures in existing data centers or to move to cloud-based solutions. The main focus of the study is on the relative costs of ownership of the two solutions, with supporting research conducted to identify sources that illustrate the inherent advantages and disadvantages of both solutions and key challenges encountered when moving from a mainframe data center approach to the cloud.

Literature is presented that identifies the key benefits of a cloud solution. One of the key benefits explored is the reported savings in operations costs that can be gained with a move off of the mainframe and to the cloud (McGill, 2012). Non-financial benefits are presented as well, including the flexibility and scalability offered by cloud solutions and the inherent disaster recovery aspects of a solution that requires the storage of data and applications in a remote (cloud) location (Dogra, 2012; McGill, 2012; Yoo, 2011).

Sources are also identified that address the inherent challenges of moving from a mainframe to a cloud-based architecture. Experts identify one challenge of migration is the fact that the move can take years (McGill, 2012); solutions presented to accomplish migrations to the cloud include rigorous, multi-step process (Lawal & Folorunso, 2013). Literature is presented that identifies the inherent risks in attempting to migrate mission-critical applications to the cloud (Brearley & Taylor, 2013; Enderle, 2014). Finally, sources are included that identify applications that are not ultimately suitable for cloud solution, as well as the applications that work best in the cloud (Rajan & Shanmugapriya, 2012, p. 44).

Research Questions

Main question. The focus of this annotated bibliography is centered on the following question: What inherent true total cost of ownership is associated with a business either staying with or migrating away from mainframe hardware in a data center environment to the purported cheaper cloud-based alternatives?

Sub-questions. To further support this area of focus the structure of this research includes the following sub-questions: (a) What are the nonmonetary advantages and disadvantages of a mainframe versus a cloud-based solution? (b) What are the inherent challenges in moving from a mainframe environment to a cloud-based solution?

Audience Description

Creswell (2014) indicates that, "...researchers write for audiences that will accept their research" (p. 21). The focus of this research is a comparison of the costs that are inherent in mainframe versus cloud-based technology platforms and the accompanying advantages, disadvantages, and challenges of the two solutions. According to Barker (2013), "...96 of the world's top 100 banks, 23 of the 25 top US retailers, and nine out of 10 of the world's largest insurance companies run IBM's System z mainframes" (para. 5). Given that there are such a substantial number of mainframes that are still operational, the audience for this study represents not only national but also global business sectors. This research has the potential of receiving high interest from businesses that are speculating about upgrading their legacy data centers from mainframes to a more modern technology.

The interested audience members, more specifically, are information technology professionals, including Chief Information Officers (CIOs), Chief Technical Officers (CTOs),

and Chief Financial Officers (CFOs) who possess significant spending authority or budget-making responsibilities. These key stakeholders are interested in knowing the cost differential, potential advantages, and potential disadvantages of the two environments.

Search Report

Search strategy. Searches are conducted using Google and Google Scholar; result sets are narrowed by placing site:.edu/.gov/.org, or other specific domain qualifiers into the search engine. This filtered approach allows only the results from these particular domains to be returned and offers more credible returns as well. Applying a few other filtering techniques limits the results returned to a manageable display of less than 100 reference sources and selecting publication dates of less than five years ensures the most recent information is obtained.

The last set of searches is conducted using the University of Oregon Libraries databases. Similar strategies are used to limit the timeframe of publication in order to ensure the most recent information is obtained.

Identified databases. Searches for the University of Oregon Libraries are conducted using the specific subject matter databases outlined below. Because the identified problem is technical in nature, initial searches are conducted within the “Computer Science” database. Likewise, since this identified problem also addresses a business aspect, a search within the “Business” database is also performed to retrieve more business specific articles rather than limiting the results to technical articles. The following databases are used to conduct searches:

- ArXiv.org
- EconLit

- Regional Business News
- Web of Science
- Computer Source
- Business Source Complete
- Factiva
- Academic Search Premier
- JSTOR
- Project Muse

Keywords. Throughout all of the specified searches combinations of the following keywords are used: mainframe, cloud, cloud computing, data centers, price, cheaper alternative, migration, and modernization. Included within the Annotated Bibliography section are 15 identified references that have been located while using the above search strategies.

Documentation approach. The tactic employed for tracking documentation for this annotated bibliography incorporates two electronic reference management tools instead of manual collection. The primary reason for using the electronic form of tracking is best explained by Creswell (2014) in that, “[h]and coding is a laborious and time-consuming process” (p. 195). The efficiencies gained with the electronic reference management tools allow more time to focus on the research problem instead of the arduous annotation process. The first method used is provided by the University of Oregon Library system that provides its users with the ability to save retrieved records for later viewing. Once saved, this method extracts pertinent information (i.e., article abstract, author, year of publication, and citation examples) about the individual article(s), thus significantly reducing the dictation practice.

The other method of accurately recording collected reference data is with the use of the “Zotero” reference management tool. This is a free open source tool that can be used to add selected content to a personal library and can be used as either a browser plug-in or a stand-alone client on either PCs or Macs (Dillard, 2012, p. 1). While searching for references outside of the University of Oregon Library environment, the Firefox browser plug-in greatly expedites the collection and retrieval process for documenting selected reference material. The combination of both methods provides an effective approach for record keeping. As Dillard (2012) mentions, “[w]hen conducting formal research, students must track and document the search process, create a bibliography, and organize references” (p. 1).

Reference evaluation criteria. The process of evaluating the included references is done to ensure the sources are applicable to either the mainframe and/or the cloud-based data center environments. The selected references are categorized into one of three areas: (a) those representing mainframe benefits; (b) those signifying cloud benefits; and (c) lastly, those that compare both platforms. In order to further evaluate the credibility of an information source, five factors identified by Bell and Frantz (2014) are used during this evaluation: relevancy, authority, objectivity, quality, and currency (para. 1). By performing both methods articles are eliminated that do not fit into any of these categories or factors because they hold no relevancy to the research problem.

Bell and Frantz (2014) include multiple points to consider when evaluating the authority of an information source. This review focused on the authors’ credentials or biographical information located within articles to determine their experience in the technology realm of mainframe or cloud computing environments. Another determination point is whether or not the authors are associated with a reputable institution or organization, which is verified with an

examination of the institution or organization website. An objectivity review checks to see what the authors' intentions and/or biases are for the articles, that is, are they trying to persuade readers to purchase a product and/or does the reported information seem valid and well-researched? The quality check makes sure the publication is aesthetically appropriate to include proper grammar, no typographical errors, and clear presentation of the material. Some of the identified references in this study do contain some typographical errors, assumed to be due to cultural differences with the spelling of certain words.

The remaining evaluating factor is currency, which checks whether or not the research topic requires the most current information. The research topic in this study requires material from the last four years; this timeline is established by Barker (2013), who states the, "...newest mainframes [were] delivered in 2010" (para. 7).

Annotated Bibliography

The Annotated Bibliography that follows provides 15 references that have been evaluated and categorized into three sections: (a) benefits of the mainframe platform, (b) benefits of the cloud platform, and (c) comparison of both platforms, related to the focus of this study of the differences in costs associated with each type of platform. Along with these categories each reference consists of three parts: (a) the APA appropriate reference style citation, (b) the authors accompanying published abstract, and (c) a summary providing more explanation about the applicability of the individual article to this study. A compilation of these elements provides greater ease to the interested audience members, including CIOs, CTOs, and CFOs during their cost comparison analyses.

Category 1: Benefits of the Mainframe Platform

Brearley, K., & Taylor, D. (2013, October). Mainframe: Vicinity yet to be explored. *Siliconindia*, 32-33.

Abstract. The authors discuss the significance of mainframe technology in daily business operation. They point out the use of mainframe as a strong place in business environment while organizations use other forms of computing. They also stress the interest of corporations to modernization solutions to preserve their business-critical mainframe application investment.

Summary. The article starts by emphasizing that the mainframe is well integrated into the business sector and a vast majority of these businesses still depend heavily on the mainframe. One reason provided for such reliance is because the mainframe is a stable and nearly-unbreakable platform for processing huge amounts of corporate data. But the

article depicts that mainframes have rising costs, and corporations are interested in doing more with less and are looking for modernized solutions. The article next mentions the cloud as an alternative to these ever-increasing mainframe costs. However, the move to the cloud is not a short-term migration path and most businesses are leery of pushing legacy applications to the cloud platform. The article then describes some shortcomings to the mainframe, including the dearth in technical talent in supporting the platform because most professionals who are well versed in mainframes are reaching the age of retirement. Given this summation, the article provides an argument for staying with the mainframe and not taking the lengthy cloud path. Instead, the authors suggest executing innovative strategies to exploit certain features to help reduce mainframe costs and modernize those features in the process as well. The authors also recommend bridging the talent gap by providing modern technology to support the newer mainframe generations to demystify the mainframe environment.

Enderle, R. (2014, April 11). The mainframe isn't dead, and neither is the PC. *CIO*. Retrieved from <http://www.cio.com/article/2377164/legal/the-mainframe-isn-t-dead--and-neither-is-the-pc.html>

Abstract. The mainframe was supposed to go extinct decades ago, but it's abundant in many habitats. Same goes for the PC, which seems to have adapted for survival better than once thought. Both the mainframe and the PC offer evolutionary advantages that newer, more sophisticated species still struggle to match.

Summary. This article discusses the mainframe favorably and conveys that the mainframe is not dead but rather is adapting to the changing IT landscape. This adaptation has proven to be successful because, as the article mentions, there are reasons

why the mainframe remains relevant. First, a large amount of software does not migrate well onto other architectures and secondly, the mainframe has unmatched massive input or output capabilities. One example mentions a CIO wanting to replace the mainframe with servers, but the associated costs with this endeavor would equate to buying three mainframes, an undesirable outcome. The article also describes that the mainframe is not necessarily the center of data centers as it once was, but with the addition of compelling vendor supplied software tools it can still function as the most critical component of the enterprise. Thus, this article provides support for the mainframe environment and showcases that even the most archaic of platforms can evolve to become cost effective and remain relevant even when the industry trend has declared it dead.

Greengard, S. (2011, June 14). Back to the mainframe. *Baseline*, 1-2.

Abstract. The article focuses on the usefulness of the mainframe computers to several companies and government agencies. Mark White, chief technology officer (CTO) and principal at Deloitte Consulting LLP, states the serviceability of such mainframes to companies and information technology, particularly those with databases. Adam Burden of Accenture denotes the relevance of this technology to businesses. The mainframes' applicability to cloud computing is also mentioned.

Summary. Greengard's article discusses the usefulness and the modernization of the mainframe. The article emphasizes that organizations that use the mainframe fall into three categories: (a) groups looking to move off the platform, (b) groups that have invested heavily in the platform, and (c) groups that use the mainframe as the mainstay of their IT infrastructure. This designation and discussion of each of these categories greatly adds to the identified research problem, especially the detail provided for the second

group because it specifically addresses the huge financial and labor investment made for the mainframe by organizations. The article discusses other benefits of staying with the mainframe including the ideas that mainframes excel at failover, load balancing, and disaster recovery; the authors also note challenges associated with the platform. The authors identify the key challenge now, for many enterprises, as finding the talent to handle development and programming tasks on mainframes. This continued discussion also supports the research problem by providing advantages and disadvantages for organizations that choose to either stay with or migrate away from the mainframe.

Niccolai, J. (2013, February 8). Ibm eyes mobile, social workloads for mainframe platform.

InfoWorld. Retrieved from <http://www.infoworld.com/article/2612977/mainframes/ibm-eyes-mobile--social-workloads-for-mainframe-platform.html>

Abstract. To help the mainframe compete against lower-cost systems, IBM is considering making it easier for customers to run their mobile and social networking apps.

Summary. This article concentrates on how the mainframe stays relevant and fends off competition from lower-cost systems. The author suggests one enhancement to help the mainframe compete against lower-cost systems by adding specialty chips (CPUs or Central Processing Units) for running workloads such as Java and Linux and introducing a smaller business class of mainframes. The author also mentions that upgrades are being considered that will make it easier for customers to run some of their mobile and even social networking applications on the mainframe. The mainframe would be the preferred platform for most big corporations to run these mobile and social applications because of the mainframe's maximum security and uptime capabilities. The author continues the

discussion with more improvements that manufactures of the mainframe are going to be undertaking in the coming years in order to stay competitive against these lower-costs systems. This reference is included to identify strengths of the mainframe and to identify further challenges in the move to a cloud-based solution based upon technical advancements.

Saran, C. (2014, April). How the mainframe remains relevant in the cloud era. *Computer Weekly*, 16-18.

Abstract. The article evaluates computer company International Business Machine's CICS application server mainframe zEnterprise.

Summary. The article illustrates the relevance of the mainframe by stating that the mainframe processes in excess of one million transactions per second – significantly more than the number of all Google searches, Twitter tweets and Facebook likes performed in the same time period (p. 16). The article further explains that the mainframe has kept up with the latest market trends by means of supporting the latest programming languages of Java and C++. However, the article does not just depict a positive argument for the mainframe, because the author notes that there are still challenges that mainframes face. One challenge is companies wanting to find cheaper alternatives to the mainframe; as a result, internet companies like Amazon, Google, and Facebook are using cheaper alternatives to run their applications. Lastly, the article mentions the potential future of the mainframe and some of the current initiatives that IBM is undertaking to ensure the success of the mainframe. This article is relevant to this research because it presents advantages of staying with the mainframe and highlights the fact that the decision to move existing architecture to the cloud cannot be made lightly.

Category 2: Benefits of the Cloud Platform

Bishnoi, A., & Khatri, P. (2014, October). Cloud computing-A new reference. *International Journal of Research*, 1(9), 635-639.

Abstract. Cloud computing has established as one of the fastest-growing segments of the information technology industry. The ability to courage economics of scale, geographic distribution, and source opened software and automated system to drive down costs makes it most attractive for business.

Summary. This article provides a summation of cloud computing. It discusses aspects of the origins of the cloud and the advantages and disadvantages of this up-and-coming computing paradigm. One advantage in the foundation of cloud computing that is included by the authors is the broader concept of converged infrastructure and shared services (p. 639). This concept is best described by Sainath, Narayandas, Jayakrishna, and Aravind (2012) by expressing “[t]his type of data center environment allows enterprises to get their applications up and running faster, with easier manageability and less maintenance, and... rapidly adjust IT resources (such as servers, storage, and networking) to meet fluctuating and unpredictable business demand”(p. 451). However, one of the disadvantages the article identifies is the fact that a dead internet connection means no work can be performed and in areas where the internet connections are few or inherently unreliable, this issue could be a deal breaker (p. 639). There are a few diagrams included that present visual aids in the working procedure flow of the cloud, a cloud pyramid showing the structure, and the cloud architecture. The content of this article is appropriate for this research paper as it provides further explanation of the cloud as an alternative to the mainframe data center.

Eviwiekpaefe, A., & Ajakaiye, F. (2014). The trend and challenges of cloud computing: A literature review. *International Letters of Social and Humanistic Sciences*, 5, 13-20.

Abstract. One of the most significant innovation in the Information Technology (IT) industry after the introduction of the personal computer and the internet is Cloud computing. The shift to cloud is a landmark in the IT industry and has raised keen interest both from the industrial community and academia. It is a new virtualization model for the quick provisioning of shared resources, software, applications and services over the internet to fulfill the elastic demand of the customer with minimum effort or interaction with the service provider. Thus cloud computing has become an interesting and increasingly essential trend. This paper presents a detailed review of Cloud Computing. It includes a discussion of the main service model of cloud computing, the general deployment models, the characteristics of Cloud computing and terminologies adopted in cloud computing. The paper also presents the trend of cloud computing and its challenges.

Summary. This article further supports the cloud and offers an ideal overview of the cloud-computing paradigm. The article covers what the cloud is, the cloud types and deployment models that can be used for each type in an organization, characteristics of a cloud, trends of the cloud over the last few computing eras, and the inherent challenges. The author also describes how cloud computing provides excellent support for infrastructures and reduces IT costs, and describes how the rapid elasticity of the cloud is able to handle varying customers' demands as well as various service and deployment models, one of the main reasons for adopting this computing system (p. 19). The selection of this article for this research problem is to support the potential solution

alternatives for organizations having to contend with the decision of staying with a mainframe solution or moving to the cloud.

Lawal, B., & Folorunso, S. (2013, December). Migrating business services and applications into the cloud. *Computing, Information Systems, Development Informatics and Allied Research Journal*, 4(4).

Abstract. Cloud computing has attracted a lot of hyperbole since it became a trendy topic for IT managers to talk about. Companies frequently trumpet their cloud enabled services but rarely give up details on precisely how they achieved this or how much of their infrastructure has been fully migrated. Security and reliability of cloud services are often raised as concerns. By understanding the basics of cloud computing and knowing how to assess important factors such as security and the identification of systems that are suitable for migration, it becomes much easier to design and implement a cloud strategy. This paper provides the essential facts about the cloud computing, list some factors to prepare for when adopting cloud computing, consideration for managers migrating their services and applications into the cloud. It also discussed the merits of going into the cloud.

Summary. The selection of this article is to further support knowledge of the cloud environment, but more specifically the migration of company infrastructures to the cloud. The paper covers information about the cloud including (a) its characteristics, (b) the four types of cloud deployment models, (c) preparing for implementation of the cloud in the workplace, (d) migrations of applications to the cloud, (e) some considerations to understand before migrating into the cloud, and (f) advantages and disadvantages to this computing method. The authors mention that migration of applications to the cloud is no easy endeavor. However, the paper offers some invaluable considerations to understand

during the preliminary meetings for organizations deciding to make this change. The suggestions are (a) prepare for migrations on a realistic timetable, and (b) prepare for cultural resistance and change (p. 24). The fact that this article presents migration challenges as well as these suggestions to address these challenges further strengthens its specific relevance for this research paper.

McGill, S. (2012, January 23). Top tips for migrating to the cloud. *The Data Center Journal*.

Retrieved from <http://www.datacenterjournal.com/it/top-tips-for-migrating-to-the-cloud/>

Abstract. As the majority of today's public sector organizations face the challenge of cutting costs across the board to meet government spending targets, one area that is coming under increasing scrutiny is IT infrastructure. As a result, cost-effective distributed IT platforms and services are being considered as an alternative to the costly proprietary minicomputers and mainframes on which many government organizations have relied for so long.

Summary. The topic of this article is focused on the cloud and how organizations can move their applications, effortlessly, to this platform. The author begins the article by noting that many critical legacy IT applications reside on mainframes, which have consistent annual maintenance and expanding upgrade fees. The mainframe has been viewed for decades as the most stable and secure environment to host applications; however, this view is starting to shift towards a preference for IT agility. The author defines agility as moving away from closed environments, modernizing applications and moving to new platforms hosted off the mainframe. The article includes best practices for organizations which decide to move applications off of the mainframe. The author lastly mentions that this transition is a time-consuming endeavor that could take up to three

years to complete, but still views this move to be beneficial for organizations because this enables a better user experience and the ability to share data in a much more efficient manner. The selection of this article is used to identify benefits of the cloud platform and to provide examples of disadvantages of the mainframe.

Rajan, A., & Shanmugapriya, S. (2012, May) Evolution of cloud storage as cloud computing infrastructure service. *Journal of Computer Engineering*, 1(1), 38-45.

Abstract. Enterprises are driving towards less cost, more availability, agility, managed risk - all of which is accelerated towards Cloud Computing. Cloud is not a particular product, but a way of delivering IT services that are consumable on demand, elastic to scale up and down as needed, and follow a pay-for-usage model. Out of the three common types of cloud computing service models, Infrastructure as a Service (IaaS) is a service model that provides servers, computing power, network bandwidth and Storage capacity, as a service to their subscribers. Cloud can relate to many things but without the fundamental storage pieces, which is provided as a service namely Cloud Storage, none of the other applications is possible. This paper introduces Cloud Storage, which covers the key technologies in cloud computing and Cloud Storage, management insights about cloud computing, different types of cloud services, driving forces of cloud computing and cloud storage, advantages and challenges of cloud storage and concludes by pinpointing few challenges to be addressed by the cloud storage providers.

Summary. This cloud article provides more information about this computing paradigm and includes the aspects of types of cloud configurations, benefits of cloud computing, and issues with the cloud. An advantage the authors discuss is making data available in the cloud; storing data in the cloud makes it easily and ubiquitously accessed, often

incurs a much lower operating cost, and increases the value of the data by enabling opportunities for enhanced collaboration for organizations (p.38). Another benefit of cloud computing is that it enables companies to shift money from capital expenses to operating expenses, which ultimately allows the enterprise to focus their money and resources on innovation (p. 40). However, the positive aspects of cloud solutions were not the only topics discussed as the authors also pointed out a few drawbacks to this platform. One concern reported is the fact that because the data is residing outside the enterprise's infrastructure, it is perceived that the enterprise may lose control over data. The explanation of all of these cloud elements in the article further supports this topic's research question of what is the inherent true total cost of ownership associated with a business either staying with or migrating away from mainframe hardware in a data center environment to the purported cheaper cloud-based alternatives.

Yoo, C. S. (2011, June 01). Cloud computing: Architectural and policy implications. *Review Of Industrial Organization*, 38(4), 405-421.

<http://dx.doi.org.libproxy.uoregon.edu/10.1007/s11151-011-9295-7>

Abstract. Cloud computing has emerged as perhaps the hottest development in information technology.... This Article offers an initial exploratory analysis in...key cloud computing concepts, such as service oriented architectures, thin clients, and virtualization, and discusses the leading delivery models and deployment strategies being pursued by cloud computing providers. It then analyzes the economics of cloud computing in terms of reducing costs, transforming capital expenditures into operating expenditures, aggregating demand, increasing reliability, and reducing latency.... It

closes by offering a few observations on the impact of cloud computing on the industry structure for data centers... as well as its implications for regulation.

Summary. This article supports the adoption of the cloud platform and provides information about the basic principles or economic foundations of the platform, as well as an analysis of the architectural and policy implications. A benefit of cloud computing presented by the author is the capability of virtualization, which the author defines as enabling the computing power of a single machine to be subdivided into a number of smaller virtual machines by permitting a single piece of hardware to run multiple operating systems or multiple sessions of the same operating system (p. 407). With this benefit, the cloud has ability to reallocate additional storage and computing power as needed, which greatly enhances the flexibility and scalability of computing operations. Other critical benefits disclosed in the article are the cost reductions and amortization of fixed costs that are associated with the cloud environment. End users who shift applications into the cloud face considerably lower maintenance costs as well as relief from the responsibility of making sure software application are upgraded to the most recent versions. A move to the cloud ensures that all software updates are deployed quickly and easily (p. 409). The author states that cloud computing holds considerable promise as a transformative technology that can change the very nature of computing. This article provides useful information on the benefits of cloud computing that can assist organizations that are contenting with the decision of staying with a mainframe solution or moving to the cloud.

Category 3: Comparison of Both Platforms

Barker, C. (2013, July 4). With the world embracing cloud computing, who needs mainframes?.

ZDNet. Retrieved from <http://www.zdnet.com/with-the-world-embracing-cloud-computing-who-needs-mainframes-7000017087/>

Abstract. Who needs a mainframe when we now have the cloud? Well, you may still find the old iron useful.

Summary. The author discusses both the mainframe and the cloud within the article, but provides more information about the usefulness of the mainframe. Of that information, one statistic explains that “[m]ainframes process roughly 30 billion business transactions per day” (para. 4) and implies that this platform is still greatly utilized. The author continues with this discussion of the mainframe, but also introduces the topic of cloud computing and whether or not it will replace the legacy mainframe system. A compelling argument against replacement of the mainframe by the cloud is because, “[m]ainframes represent a major expense and at the same time they are often running mission critical applications... often vital, to the financial health of a company” (para. 26). Not only does this sentiment provide relevancy for this research topic, but the statement that “business risk and cost of migration means the return on investment on decommissioning these systems is just not there” (para. 27), further substantiates this article for this research problem.

Hardiman, N. (2014, February 21). The mainframe evolves into a new beast in the cloud era.

TechRepublic. Retrieved from <http://www.techrepublic.com/article/the-mainframe-evolves-into-a-new-beast-in-the-cloud-era/>

Abstract. Cloud computing didn't kill the mainframe. The disruptive technology did, however, cause the mainframe to evolve.

Summary. The subject matter of this article is primarily focused on the mainframe but secondarily the cloud is also discussed. The author initially indicates the cloud inherited its consumption-based pricing model and Linux virtual machines from the mainframe platform. The author states that the mainframe is not a machine built for ordinary workloads, but instead, is used to operate large workloads such as credit card transactions of a bank or managing the databases of an insurance company. The author further explains why the mainframe has not completely been removed from the workforce: (a) business-critical applications running on the mainframe cost a fortune to migrate elsewhere, and (b) the ability it has to run virtual machines and store a tremendous amount of data internally. Lastly, the author discusses how the mainframe will remain useful in the modern cloud world, despite the platform's associated high operating costs, because when analyzing the mainframe's hardware and its capability of running enterprise-wide workloads it may ultimately be cheaper than the cloud alternative hardware. The selection of this reference is used to provide information on the benefits of the mainframe platform while also providing a comparison to the cloud platform.

Otey, M. (2011, June). Is the cloud really just the return of mainframe computing? *Windows IT Pro*, 17(6), 4.

Abstract. The author comments on cloud computing and the interest shown by businesses in cloud offerings. He cites the reluctance of information technology (IT) to jump headstart into the cloud. He points out that cloud computing is the same as the old centralized IT processing model embodied by the mainframe. He compares cloud with

mainframes, in that they both move the computing power away from the users. He also mentions the factors which led to the emergence of distributed computing.

Summary. This article was selected to reflect some drawbacks of using either of the two computing paradigms. The author mentions that many IT departments are not supporting the cloud movement quite yet. A primary reason for this resistance is because these services harken back to an era of computing that fell out of favor - the era of the mainframe - because the computing power has moved away from the end users and into a centralized entity that is managed by someone else (p. 4). The author continues with this idea for the remainder of the article and mentions that these factors are what led to the rise of distributed PC computing, client/server computing, and the web that we use today. The author then concludes the article with a question for businesses, do they continue with the centralized computing environment or proceed with the distributed platform?

Tsai, B., & Shen, J. (2012). Securities operations: In-house or in the cloud?. *Journal of Securities Operations & Custody*, 5(2), 110-117.

Abstract. The architecture of IT infrastructure has evolved from what was once a mainframe system to personal computing in recent decades. As cloud computing proliferates in today's environments, we see a reversion to the mainframe system. The level for computing and processing power in the asset management industry, and in general, allows for cloud computing to be widely used. The business of asset management can also allow a discipline of having low capital expenditure and minimising [sic] of depreciation assets. A cost-benefit discussion in this paper reveals many ways in which cloud computing makes sense from the facets of e-mail, file storage, and trading and accounting applications.

Summary. The inclusion of this article for this research topic focuses on the needs of the intended audience, because as the article mentions, chief operating/financial/technical officers have recently been faced with an array of factors for consideration (p. 112) with the decision of whether to move to a cloud infrastructure. The authors focused on factors such as a manager's decision to either host an e-mail file system internally or within the cloud. Another decision factor highlighted by the authors is security requirements and the importance of managers investing in secure storage and not just relying on initial provisions from vendors. One final factor discussed is a brief financial consideration of ownership versus a subscription model. Along with these considerations, the authors emphasize that managers need to examine the benefits and risks of each of these factors because they will offer a framework when choosing to use cloud technology.

Conclusion

The Annotated Bibliography with the selected 15 references presents distinct results concerning this research topic about the decision to stay with the legacy mainframe platform or migrate to the cloud platform. The references are organized into three different categories: (a) benefits of the mainframe platform, (b) benefits of the cloud platform, and (c) the comparison of both platforms. The Abstract and Summary elements of the references highlight the unique perspectives that the authors present for their respective platform articles. These findings are also included in Table 1 and Table 2, which illustrate the benefits of both platforms. This type of information will be used by the intended audience of this study to further understand the associated benefits that are presented by both data center environments.

Table 1***The Mainframe Platform – 3 Key Findings***

Key Findings	Description
Characteristics	A big, powerful, expensive, and reliable computer that has been around for decades; an established platform for running a successful enterprise data center(Hardiman, 2014; Saran, 2014)
Longevity	Continued widespread use of the mainframe showcases that even the most archaic of platforms can evolve and remain relevant (Enderle, 2014)
Overcome High Costs	Despite the high cost, mainframe use may be cheaper than cloud hardware use for enterprise-scale workloads (Hardiman, 2014)
<i>Note:</i> Adapted from Enderle (2014); Hardiman (2014); and Saran (2014) references.	

Table 2***The Cloud Platform – 3 Key Findings***

Key Findings	Description
Characteristics	Excellent support for flexible infrastructures, applications and services; helps reduce IT costs; and able to handle varying customers' system demands (Eviwiekpaefe & Ajakaiye, 2014)
Virtualization Capability	Create virtual versions of hardware platforms, Operating Systems, and storage device or network resources, in order to reduce energy and hardware costs from server consolidation (Eviwiekpaefe & Ajakaiye, 2014)
Backup Capability	Much easier to back up and restore information to the cloud than storing the same information on a physical device (Lawal & Folorunso, 2013)
<i>Note:</i> Adapted from Eviwiekpaefe and Ajakaiye,(2014); and Lawal and Folorunso (2013) references.	

One perspective presented for the mainframe is that it is a big, powerful, expensive, and reliable computer that has been around for decades (Hardiman, 2014, para. 5). Saran (2014) characterizes the mainframe as a time-honored platform for running a successful enterprise data

center (p. 18). Another perspective presents that the mainframes will continue their presence in the business sector for the foreseeable future because "...predictions about the demise of mainframes are largely exaggerated" (Greengard 2011, p. 2). As documented by Enderle (2014), the continued widespread use of the mainframe showcases that even the most archaic of platforms can evolve and remain relevant if the people who manage the platform act to enable its evolution (para. 17). A final perspective that Hardiman (2014) documents is the question of whether a mainframe can deliver computing features such as agility that are comparable to the same features with a cloud configuration; he notes that mainframes can be more useful than a fleet of cloud boxes, but only for certain types of work. Hardiman (2014) states that it is doubtful that organizations are going to buy new mainframes for small workloads, instead reserving the purchase of these expensive machines for large-scale workloads where the superior processing power of the mainframe provides an advantage. He notes, however, that despite the high cost, mainframe use may be cheaper than cloud hardware use for enterprise-scale workloads (para. 17).

The recognition of the continuing endurance of the mainframe presents one of its major shortcomings as the talent to operate these systems is starting to dwindle because of aging and retiring mainframe professionals ("Managing mainframe costs," 2013, p. 4). However, the introduction of new features and more-advanced capabilities for the mainframe (Greengard, 2011, p. 2) will better prepare new mainframe professionals to successfully backfill these vacant positions. One such feature Henderson (2012) presents is a Windows Graphical User Interface (GUI) for the mainframe platform to simplify Virtual Telecommunication Access Method (VTAM) administration, DB2 administration, or system software upgrades (para. 4) instead of using the old command level interaction approach for administrative mainframe tasks. The

introduction of this GUI and other more modern capabilities could position the mainframe to overcome the support deficiency posed by the more dated interface methods typically associated with the mainframe, thus supporting the mainframe's continued dominance as a critical component of the data center environment.

The more modern cloud computing module does not suffer from the same lack of trained support professionals as the mainframe because the resources, including expensive networking equipment, servers, and IT personnel are shared, resulting in reduced costs (Rajan & Shanmugapriya, 2012, p. 40). The cloud offers many other advantages, including excellent support for flexible infrastructures, applications and services; reduced IT costs; and the ability to handle varying customers' demands. All of these benefits factor into the decision to adopt a cloud architecture (Eviwiekpaefe & Ajakaiye, 2014, p. 19). Despite the hype surrounding cloud computing, more and more C-level executives and IT decision makers agree that it is a real technology option (Lawal & Folorunso, 2013, p. 26). A perspective discussed by Eviwiekpaefe and Ajakaiye (2014) addresses virtualization and the creation of virtual versions of hardware platforms, operating systems, and storage devices or network resources. This capability promises great opportunities for reducing energy and hardware costs through server consolidation (p. 15), both of which draw high interest from stakeholders who want to know the cost differential of this environment. Another viewpoint discussed by Lawal and Folorunso (2013) is that backing up and restoring information to the cloud is much easier than storing the same information on a physical device (p. 27). The benefits associated with the cloud do contain some appealing characteristics for organizations considering this move to an alternative data center, making the cloud a valuable platform option for decision makers.

The concluding category in the annotated bibliography provides a comparison of the two platforms and proponents for both. Various scholars note that the cloud is not a superior solution to the mainframe in all cases. Otey (2011) states that the cloud is a return to the mainframe architecture as the cloud is a return to the old centralized IT processing model of mainframe computing. He notes that the cloud and mainframe are alike in that they both move the computing power and infrastructure governance farther from the end users and closer to a centralized entity managed by someone else (p. 4). Barker (2013) states that if cloud solutions are to remain competitive with the mainframe's successful large-scale workload performance they will need to offer comparable functionalities like scalability and flexible payment options for organizations (para. 14). The security assurance that the current cloud computing systems offer security professionals is unreliable because of the need to support both internal and external clients (Sainath, Narayandas, Jayakrishna, & Aravind, 2012, p. 455). The security concern is another aspect that the cloud platform will need to improve upon to stay competitive because the mainframe is considered to be reliable, easy to service, and a highly secure platform ("Managing mainframe costs," 2013, p. 1)

In closing, the compilation of the 15 references presents literature that helps inform organizational decision makers in their decisions of whether to stay with existing mainframe architectures in their current data centers or to move to cloud-based solutions. Multiple key findings are presented that represent the mainframe and the cloud, as well as a few articles providing comparison information about both environments. Conclusions drawn from the research are that executives tasked with determining which platform to operate face a difficult decision because the characteristics of both platforms share comparable functionalities and both offer comparable benefits to an organization's infrastructure. A careful analysis that considers

the benefits and risk of each alternative for a specific organization, along with a consideration of the corresponding capital and operating costs, is necessary before selecting from the two options.

References

Barker, C. (2013, July 4). With the world embracing cloud computing, who needs mainframes?.

ZDNet. Retrieved from <http://www.zdnet.com/with-the-world-embracing-cloud-computing-who-needs-mainframes-7000017087/>

Bell, C., & Frantz, P. (2014, July). Critical evaluation of information sources. *UO Libraries*.

Retrieved from <http://library.uoregon.edu/guides/findarticles/credibility.html>

Bishnoi, A., & Khatri, P. (2014, October). Cloud computing-A new reference. *International Journal of Research*, 1(9), 635-639.

Brearley, K., & Taylor, D. (2013, October). Mainframe: Vicinity yet to be explored. *Siliconindia*, 32-33.

Creswell, J. W. (2014). *Research design: Qualitative, quantitative, and mixed methods approaches*. (4th ed.). Thousand Oaks, CA: SAGE.

Dillard, A. (2012). A preliminary exploration of zotero for use in aim capstone. *UsingZotero* [PDF Document], 1-3.

Dogra, R. (2012, January 20). Let cloud computing save you some money. *The Data Center Journal*. Retrieved from <http://www.datacenterjournal.com/the-daily-buzz/let-cloud-computing-save-you-some-money/>

Enderle, R. (2014, April 11). The mainframe isn't dead, and neither is the PC. *CIO*. Retrieved from <http://www.cio.com/article/2377164/legal/the-mainframe-isn-t-dead--and-neither-is-the-pc.html>

Energy efficiency for data center buildings. (2014). 42 U.S.C. §17112.

Eviwiekpaefe, A., & Ajakaiye, F. (2014). The trend and challenges of cloud computing: A literature review. *International Letters of Social and Humanistic Sciences*, 5, 13-20.

Greengard, S. (2011, June 14). Back to the mainframe. *Baseline*, 1-2.

Hardiman, N. (2014, February 21). The mainframe evolves into a new beast in the cloud era. *TechRepublic*. Retrieved from <http://www.techrepublic.com/article/the-mainframe-evolves-into-a-new-beast-in-the-cloud-era/>

Henderson, S. (2012, February 15). The effective CIO: Mainframe staffing. *Enterprise Systems Media*. Retrieved from <http://enterprisesystemsmedia.com/article/the-effective-cio-mainframe-staffing>

Lawal, B., & Folorunso, S. (2013, December). Migrating business services and applications into the cloud. *Computing, Information Systems, Development Informatics and Allied Research Journal*, 4(4).

Managing mainframe costs: Controlling costs, while improving performance and productivity. (2013, February). *Hewlett-Packard*, 1-8. Retrieved from <http://h20195.www2.hp.com/V2/GetPDF.aspx/4AA3-8428ENW.pdf>

McGill, S. (2012, January 23). Top tips for migrating to the cloud. *The Data Center Journal*. Retrieved from <http://www.datacenterjournal.com/it/top-tips-for-migrating-to-the-cloud/>

Niccolai, J. (2013, February 8). Ibm eyes mobile, social workloads for mainframe platform. *InfoWorld*. Retrieved from <http://www.infoworld.com/article/2612977/mainframes/ibm-eyes-mobile--social-workloads-for-mainframe-platform.html>

- Otey, M. (2011, June). Is the cloud really just the return of mainframe computing? *Windows IT Pro*, 17(6), 4.
- Rajan, A., & Shanmugapriya, S. (2012, May) Evolution of cloud storage as cloud computing infrastructure service. *Journal of Computer Engineering*, 1(1), 38-45.
- Sainath, N., Narayandas, V., Jayakrishna, S., & Aravind, N. (2012, March) Analysis of cloud computing security considerations for infrastructure as a service. *International Journal of Engineering Research and Application*, 2(1), 451-456.
- Saran, C. (2014, April). How the mainframe remains relevant in the cloud era. *Computer Weekly*, 16-18.
- Tsai, B., & Shen, J. (2012). Securities operations: In-house or in the cloud?. *Journal of Securities Operations & Custody*, 5(2), 110-117.
- Yoo, C. S. (2011, June 01). Cloud computing: Architectural and policy implications. *Review Of Industrial Organization*, 38(4), 405-421.
- <http://dx.doi.org.libproxy.uoregon.edu/10.1007/s11151-011-9295-7>