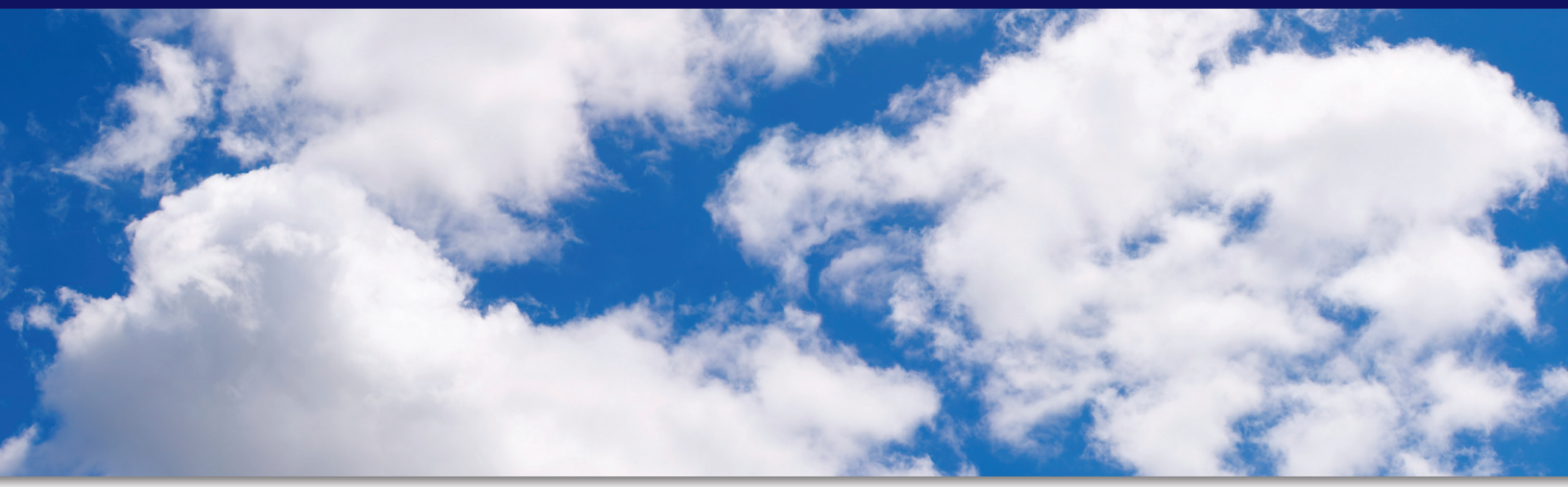
The Economics of Cloud Computing

Addressing the Benefits of Infrastructure in the Cloud



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The federal government is embracing cloud computing as a means of reducing expenditures for information technology (IT) infrastructure and services—trading up-front investment for significant outyear savings. Booz Allen Hamilton has conducted an economic analysis to investigate the potential savings of the federal plan, focusing on IT data centers and using a proprietary cost model and extensive experience in cost and economic analysis of government IT programs. Our results generally confirm the government's expectations of significant cost savings; for a non-virtualized 1,000-server data center, the benefit-to-cost ratios (BCR) in the study reflected in this paper range from 5.7 to 15.4 (with BCRs for larger data centers ranging potentially as high as 25). Our analysis implies that, over a 13-year life cycle, the total cost of implementing and sustaining a cloud environment may be as much as two-thirds lower than maintaining a traditional, non-virtualized IT data center. Our study takes into consideration transition costs and life-cycle operations, as well as migration schedules—which other studies usually ignore or treat incidentally—to arrive at BCRs that reflect the realities of transitioning major IT activities and reveal what federal enterprises can expect to realize from a transition to cloud computing. Other studies often focus only on cost savings from hardware replacement and omit some of these considerations, which may result in higher BCRs in a much shorter investment payback period that does not, in our view, paint an accurate picture.

Introduction

The President's budget for fiscal year 2010 (FY10) includes $75.8B in IT spending, which is a 7-percent increase from FY09. Of this, at least $20B will be spent on IT infrastructure investments.[1] The FY11 budget for IT is projected to be nearly $88B. The government cannot maintain this spending trajectory and has actively sought ways to reduce IT costs. Most recently, the budget submitted to the Congress highlights opportunities for the federal government to achieve significant long-term cost savings through the adoption of cloud computing technologies:

"Of the investments that will involve up-front costs to be recouped in outyear savings, cloud-computing is a prime case in point. The federal government will transform its Information Technology Infrastructure by virtualizing data centers, consolidating data centers and operations, and ultimately adopting a cloud computing business model. Initial pilots conducted in collaboration with federal agencies will serve as test beds to demonstrate capabilities, including appropriate security and privacy protection at or exceeding current best practices, developing standards, gathering data, and benchmarking costs and performance. The pilots will evolve into migrations of major agency capabilities from agency computing platforms to base agency IT processes and data in the cloud. Expected savings in the outyears, as more agencies reduce their costs of hosting systems in their own data centers, should be many times the original investment in this area."[2]

The language in the budget makes three key points: (1) up-front investment will be made in cloud computing, (2) long-term savings are expected, and (3) the savings are expected to be significantly greater than the investment costs.

An operating agency—the General Services Administration (GSA)—has been identified to focus the government efforts in cloud computing and to provide a "storefront" where other government agencies can obtain IT services. Initially, GSA will provide managed access to public cloud providers. Over time, private and hybrid cloud environments will be created to meet the IT needs of government agencies.

Booz Allen has created a detailed cost model that has capabilities for creating life-cycle cost (LCC) estimates of public, private, and hybrid clouds. We used this model, and our extensive experience in

[1] Figures from INPUT data for the FY10 President's budget; of the $20B in expenditures categorized as office automation and IT infrastructure spending, about $12.2 B is spent on major IT investments, with the remainder on non-majors. Additional expenditures on application-specific IT infrastructure are typically reported as part of individual IT investments.

[2] President's budget, FY10 (Analytical Perspectives).

economic analysis of IT programs, to arrive at a first-order estimate of each of the three key points in the President's budget. Overall, it appears likely that the budget's expectations can be met, but several factors could affect the overall degree of economic benefit.

Economic Implications

Given the nearly $76B in planned FY10 IT expenditures, and current as well as projected budgetary pressures, the Administration's drive to seek long-term cost savings is readily understandable. Yet despite some of the more enthusiastic claims of return on investment made by various cloud computing advocates, the government's adoption of this new IT model warrants careful consideration of the broad economic implications—both the potential long-term benefits in terms of cost savings and avoidance and the near-term costs and other impacts of a transition from the current environment. Factors such as the number and rate of federal agencies adopting cloud computing, the length of their transitions to cloud computing, and the cloud computing model (public, private, or hybrid) will all affect the total costs, potential benefits, and time required for the expected benefits to offset the investment costs.

Over the past 5 years, the government has made major efforts to move toward shared services in other areas, such as financial management, with mixed success. For example, although some smaller agencies have indeed migrated to shared services providers, larger agencies have generally continued to maintain their own solutions. Overall, progress has been slower than originally envisioned, highlighting the need for policy guidance and coordination.

To explore the potential economic and budgetary implications of a movement to adopt cloud computing, we drew on our experience with individual agencies and bureaus that have virtualized their IT infrastructure, as well as lessons learned from shared services initiatives led by the Office of Management and Budget (OMB) over the last several years.

We developed a first-order economic analysis by considering how agencies might migrate to a cloud-based environment and what the costs and potential savings might be under a variety of scenarios. Specifically, given long-standing efforts to protect the privacy and security of the federal government's data and systems, a key variable will be whether agencies seek savings by taking advantage of public clouds, by building their own private clouds, or by adopting a hybrid approach. For simplicity, we focused only on infrastructure services. Software as a Service will be slower to materialize because most software companies are still struggling to define licensing practices and pricing models for virtual environments. Further, consistent with OMB direction for past initiatives, we assume that migration decisions will be made at the department or agency (rather than bureau) level in order to aggregate demand and drive scale efficiencies.

Next, we developed three high-level scenarios that represent potential migration paths. We assume the perceived sensitivity of an agency's mission and data will drive its decisions on which path to follow, at least for the foreseeable future. The three scenarios are as follows:

Scenario 1: Public Cloud Adopters

Definition: Department or agency migrates its IT infrastructure to an existing public cloud.

Key Agency Characteristic: Relatively low level of mission, bureau, or program-specific sensitivities; these agencies may be the most likely early adopters of cloud computing.

Examples: Department of Commerce, Department of Labor, Environmental Protection Agency, Department of the Interior, Department of Transportation, Small Business Association, other small or independent agencies (e.g., National Archives, Army Corps of Engineers, Smithsonian).

Assumptions: Transition to the new cloud environment will occur steadily over 3 years; workload remains constant (i.e., no increase in capacity demand).

Scenario 2: Hybrid Cloud Adopters

Definition: Department or agency builds a private cloud solution to handle the majority of its IT workload but also uses a public cloud solution to provide "surge" support and/or support for low-sensitivity applications.

Key Agency Characteristic: Bureau or program-specific payment and/or privacy sensitivities; because of the inherent complexity of this scenario, these agencies are more likely to be part of the "second wave" of cloud adopters.

Examples: Department of Agriculture, Department of Education, Department of Health and Human Services, Department of Housing and Urban Development, Department of Veterans Affairs, National Science Foundation, National Aeronautics and Space Administration, Office of Personnel Management, some regulatory agencies (e.g., Federal Communications Commission, Federal Trade Commission).

Assumptions: Seventy-five percent of the IT server workload will migrate to a private cloud, and the remaining 25 percent will be transitioned to a public cloud; transition to the new cloud environments will occur steadily over 3 years; existing facilities will be used (i.e., no new investment is required in physical facilities) and workload remains constant (i.e., no increase in capacity demand).

Scenario 3: Private Cloud Adopters

Definition: Department or agency builds its own private cloud solution or participates in an interagency cloud solution.

Key Agency Characteristic: Broad mission sensitivity; given the perceived risk, these agencies may be more likely to be late adopters of cloud solutions.

Examples: Department of Treasury, Department of Justice, Department of State, U.S. Agency for International Development, Department of Energy, Nuclear Regulatory Commission, Social Security Administration, Intelligence Community (includes Department of Homeland Security), Department of Defense, GSA (i.e., community cloud), financial regulatory agencies (e.g., Federal Reserve Banks, Securities and Exchange Commission, Federal Deposit Insurance Corporation).

Assumptions: Transition to the new cloud environment will occur steadily over 3 years; existing facilities will be used (i.e., no new investment is required in physical facilities); workload remains constant (i.e., no increase in capacity demand).

To determine the potential aggregate costs and savings across the federal government, one would ideally model these scenarios using each agency's current budget for data centers. Data centers capture the most significant portion of the costs associated with moving IT infrastructure to the cloud. However, agencies publicly report only their "consolidated" IT infrastructure expenditures, which include end-user support systems (e.g., desktops, laptops) and telecommunications. Additional spending on application-specific IT infrastructure is typically rolled up into individual IT investments.

We used an alternate approach in our study, extrapolating findings based on our experience with actual data centers. Specifically, we developed a "representative" agency data center profile that, we believe, can serve as a useful proxy for other agencies and enable us to explore the potential savings of a migration to cloud computing under the scenarios described above. Although agencies of similar size can have very different IT infrastructure profiles, we modeled an agency with a classic standards-based web application infrastructure, representative of the type of IT infrastructure most suitable for a cloud computing migration. For our representative agency, we began with an assumption that the status quo (SQ) data center containing 1,000 servers with no virtualization is already operational.[3]

Using a Booz Allen-developed proprietary cloud computing cost and economic model that employs data collected internally, data from industry, and parametric estimating techniques, we estimated the LCCs for our representative agency to migrate its IT infrastructure

[3] The 1,000 servers are further broken down in our cost model by size (small, mid-sized, and large) based on actual proportions consistent with our experience.

(i.e., its server hardware and software) to the cloud under each of the three scenarios described above. We compared these costs to the LCCs of the SQ scenario (i.e., no cloud migration).

Our model focuses on the costs that a cloud migration will most likely directly affect; i.e., costs for server hardware (and associated support hardware, such as internal routers and switches, rack hardware, cabling, etc.), basic server software (OS software, standard backup management, and security software), associated contractor labor for engineering and planning support during the transition phase, hardware and software maintenance, IT operations labor, and IT power/cooling costs. It does not address other costs that would be less likely to vary significantly between cloud scenarios, such as storage, application software, telecommunications, or WAN/LAN. In addition, costs for government staff are not included. Further, costs for physical facilities are not included because of the assumption that for scenarios 2 and 3, existing facilities will be available and there will be a "wash" cost between the existing and new cloud environments.

The summary cost results are shown in the top portion of Exhibit 1, which presents the one-time investment phase costs as well as the recurring operations and support (O&S) phase costs for each scenario with a 13-year life cycle (3-year investment phase and 10-year steady-state O&S phase) from FY10 through FY22. In line with the assumed 3-year transition period for each scenario, investment costs are expected to be incurred from FY10 to FY12 and include hardware procurement and commercial off-the-shelf (COTS) software license fees; contractor labor required for installation, configuration, and testing; and technical and planning support (i.e., system engineering and program management costs) before and during the cloud migration. Because the SQ reflects an operational steady state, no investment costs are estimated for that scenario. Initially, one might assume that migrating to the public cloud scenario would not pose any up-front investment costs because there are no hardware or software procurement costs. However, there will be a need for program planning and technical support, software engineering support for "porting" the applications over to the new cloud environment, and testing support for the transitioned applications during the migration to ensure the system is working correctly in the new environment.

For all cloud scenarios, recurring O&S costs "ramp up" beginning in FY10 and enter steady state in FY13, continuing through FY22. For private clouds, these costs include hardware and software maintenance, periodic replacement/license renewal costs, system operations labor support costs, and IT power and cooling costs. For hybrid clouds, the O&S costs include the same items as the private cloud (albeit on a reduced scale), as well as the unit consumption costs of IT services procured from the public cloud. For public cloud scenarios, the O&S costs are the unit costs of services procured from the cloud provider and a small amount of IT support labor for the cloud provider to communicate any service changes or problems. In all three cloud scenarios, a significant portion of the O&S costs are SQ O&S phase-out costs during the transition phase. The SQ phase-out costs "ramp down" from FY10 to FY12, dove-tailing with the ramp up of the new clouds' O&S costs. The SQ phase-out costs are necessary to provide a proper "apples-to-apples" life-cycle comparison of the new cloud and the SQ environment. Not surprisingly, Exhibit 1 shows the total LCCs are lowest for the public cloud scenario and highest for the private cloud scenario, with the hybrid cloud scenario's LCCs falling in the middle.

We used three common metrics to analyze each scenario's potential economic benefits. These metrics allowed us to evaluate the three elements of the business case in the President's budget and estimate the absolute and relative benefits, as well as the time over which outyear savings will pay back the investment costs.

The three key metrics used in our analysis are as follows:

- **Net present value (NPV)** is calculated as each cloud scenario's discounted net benefits (i.e., the cloud scenario's reduced O&S costs relative to the SQ environment's O&S costs) minus the cloud's discounted one-time investment costs. A positive dollar figure indicates a positive economic benefit versus the SQ environment. NPV is an absolute economic metric.
- **Benefit-to-cost ratios (BCR)** is calculated as each cloud scenario's discounted net benefits divided by its discounted investment costs. A number greater than 1.0 indicates a positive economic benefit versus the SQ environment. BCR is a relative economic metric.
- **Discounted payback period (DPP)** reflects the number of years (from FY10) it takes for each scenario's accumulated annual benefits to equal its total investment costs.

Using our cost model, we estimated the LCCs for each of the cloud deployment scenarios and calculated their associated economic metrics. Exhibit 1 provides the results of this analysis.

The economic results summarized in the bottom portion of Exhibit 1 show that, as we would expect, the projected NPV and BCR for all three scenarios are significant relative to the SQ environment. Once the cloud migrations are completed, our model suggests annual O&S savings in the 65–85 percent range, with the lower end attributable to the private cloud scenario and the upper end associated with the public cloud scenario. Because we lack a reliable estimate of the government's current spending specifically on data centers, we did not attempt to apply this percentage to an overall dollar figure to estimate the potential absolute savings across the federal government. (As part of the Information Technology Infrastructure Line of Business [ITI LoB] initiative, GSA is coordinating a benchmarking effort across the government, however. If those figures are shared publicly in the future, this type of estimate should be possible). Our model shows that the net benefits and payback for agencies adopting the hybrid cloud scenario are closer to those for the private cloud than the public cloud. This variation is largely a result of our assumption that 75 percent of the current server workload would migrate to a private cloud and only 25 percent would transition to the public cloud. If we were to instead assume the opposite mix (i.e., 25 percent of the workload migrating to a private cloud and 75 percent to a public cloud), the hybrid scenario economic results would be closer to the public cloud results. Note in Exhibit 1 that even in the public cloud scenario, there are investment costs of $3.0 million for technical and planning labor support before and during the migration phase.

Exhibit 1 | LCCs and Economic Summary

Costs/Economic Metrics	Status Quo: 1,000 Server (Non-Virtualized) Environment	Scenario 1: Public Cloud	Scenario 2: Hybrid Cloud	Scenario 3: Private Cloud
Investment Phase Costs FY10–12 (BY09 M$)	$0	$3.0	$6.1	$7.0
O&S Phase Costs FY10–22 (BY09 M$)	$77.3	$22.5	$28.9	$31.1
Total LCCs (BY09 M$)	$77.3	$25.5	$35.0	$38.1
Economic Metrics:				
NPV (BY09 M$)	N/A	$41.8	$33.7	$31.1
BCR	N/A	15.4	6.8	5.7
DPP (Years)	N/A	2.7	3.5	3.7

Exhibit 2 | Public Cloud

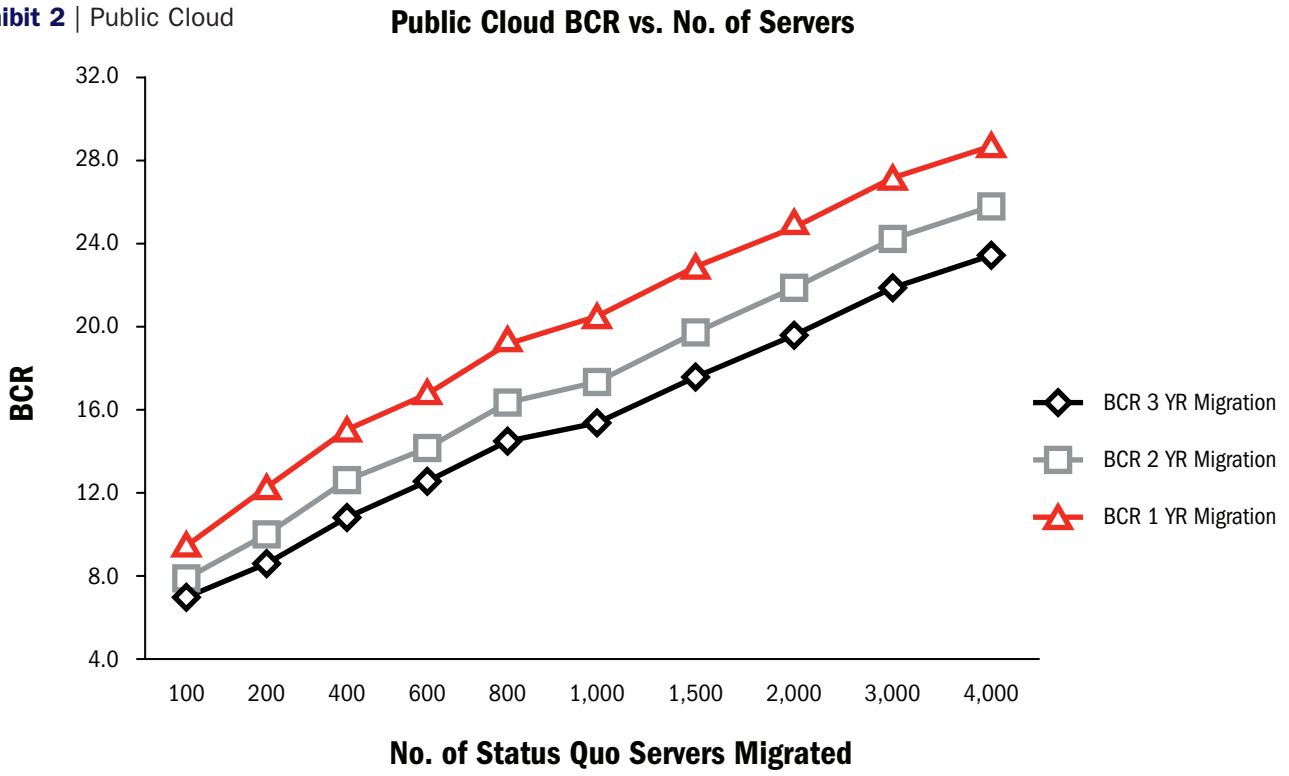


Exhibit 3 | Hybrid Cloud

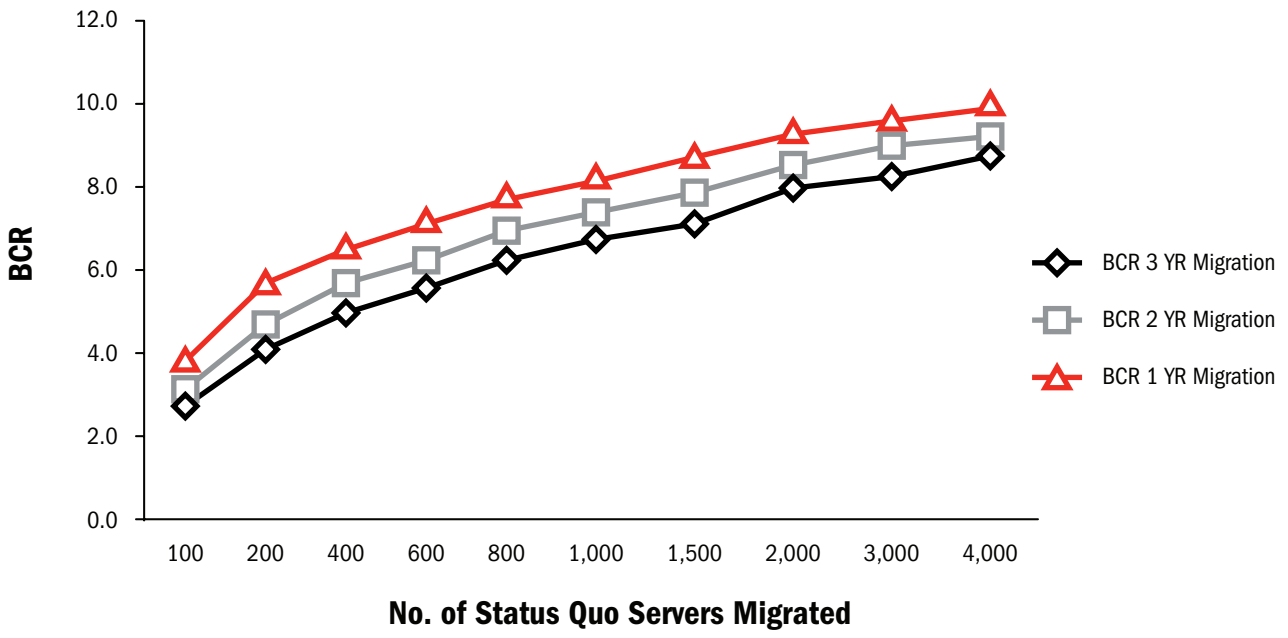
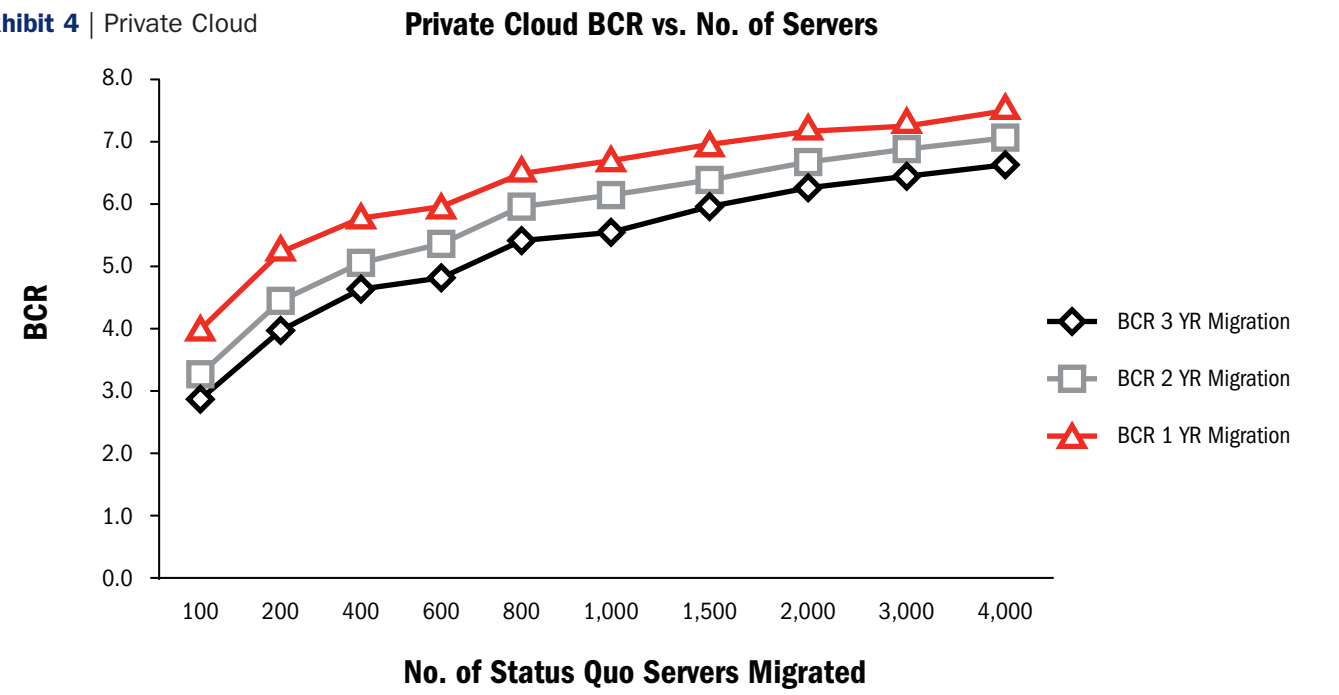


Exhibit 4 | Private Cloud



We conducted a sensitivity analysis on several of the variables in our cost model to determine the major drivers for cloud economics. Our analysis indicated that the two most influential factors driving the economic benefits are (1) the reduction in hardware as a smaller number of virtualized servers in the cloud replace physical servers in the SQ data center and (2) the length of the cloud migration schedule. Exhibits 2, 3, and 4 show the results of varying these factors.

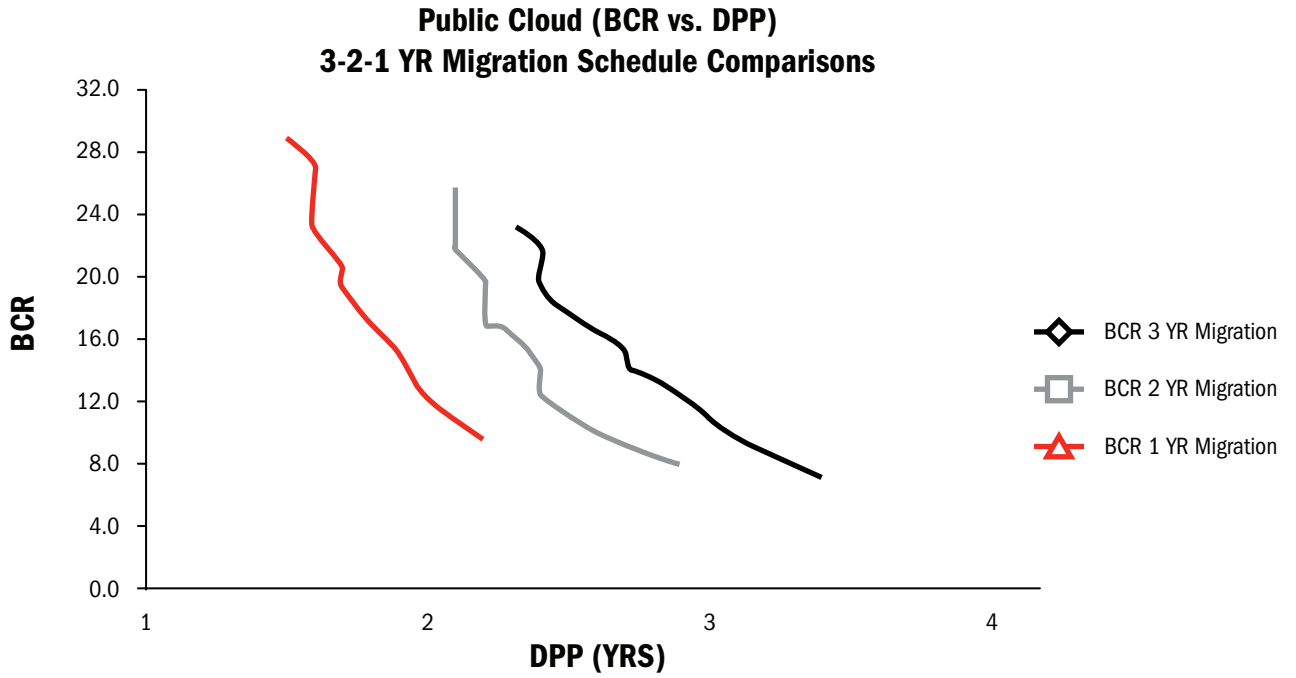
The horizontal axis in Exhibits 2, 3, and 4 represents the number of servers in the SQ environment. The vertical axis represents the corresponding BCR that results from replacing traditionally hosted servers with virtualized servers in the cloud environment. The three lines in each chart reflect an assumption of 1-, 2-, and 3-year migration schedules.

In practice, several factors could cause agencies to realize lower economic benefits than our analysis suggests, including the underestimation of any of the costs associated with the investment or O&S phases for the cloud scenarios. However, server utilization rates (both in the current environment and the new cloud environment) warrant particular attention. In our experience supporting multiple agencies of varying sizes, servers are typically significantly underutilized. Our analysis assumes an average utilization rate of 12 percent of available CPU capacity in the SQ environment and 60 percent in the virtualized cloud scenarios. This difference in server utilization, in turn, enables a large reduction in the number of servers (and their associated support costs) required in a cloud environment to process the same workload relative to the SQ environment. Agencies with relatively high server utilization rates should expect lower potential savings from a virtualized cloud environment. However, given a set of cost data and server utilization rates, the two major trends (i.e., the number of servers to be migrated and the migration schedule) should apply to all cloud migration initiatives.

The three figures indicate two key findings:

- **Scale is important:** The economic benefit increases as virtualized servers in the cloud environment replace larger numbers of underutilized servers in the SQ environment.

Exhibit 5 | Impact of Migration Schedule on Economic Benefits



- **Time is money:** Because of the cost of parallel IT operations (i.e., cloud and non-cloud), the shorter the server migration schedule, the greater the economic benefits.

These findings, in turn, lead to the following recommendations for agencies and policymakers contemplating a cloud migration:

- From an economic perspective, it is better to group smaller existing data centers together into as large a cloud as possible, rather than creating several smaller clouds, to realize scale efficiencies.
- Because of the cost of running parallel operations, government organizations should strive to properly plan for and then migrate to the new cloud environment as quickly as possible. The three lines in Exhibit 5 show that for the public cloud, the BCR goes down rapidly and the DPP increases as the transition time increases.

A final note on the economic implications of a cloud migration is worth mentioning. To keep the analysis simple, our study assumed there would be no growth in an agency's IT workload after migration to a cloud environment. However, industry studies show that an organization's IT workload tends to increase after a cloud migration.

Budgeting Implications

A few agencies, such as the Defense Information Systems Agency, are already moving quickly to explore cloud computing solutions and are even redirecting existing funds to begin implementations. However, for most of the federal government, the timeframe for reprogramming IT funding to support cloud migrations is likely to be at least 1–2 years given that agencies formulate budgets 18 months before receiving appropriations.

Specifically, IT investment requests are developed each spring and submitted to OMB in September, along with an agency's program budget request, for the following government fiscal year (GFY). OMB reviews agency submissions in the fall and can implement funding changes via passback decisions (generally in late November) before submitting the President's

budget to the Congress in February. Theoretically, the earliest opportunity for OMB to push agencies to revise their IT budgets to support a transition to the cloud will be fall 2009; however, agencies typically only have about 1 month to incorporate changes to their IT portfolios during passback. To give GSA and OMB time to develop more detailed guidance, as well as necessary procurement mechanisms and vehicles, it is more likely that OMB will direct or encourage agencies to plan for cloud migrations during the FY12 budget cycle (starting in the spring of 2010).

Economic Influence on Policy

From an economic perspective, GSA and OMB can take a number of steps to maximize the probability that the cloud computing business model can work in the federal government; i.e., that it can achieve its key objective of enabling significant cost savings. These steps include promoting information sharing and transparency into the realistic costs and benefits of various cloud models, as well as establishing the necessary policy and contracting frameworks. Because scale is a key variable affecting both costs and benefits, policy guidance regarding scale considerations will be particularly critical (e.g., determining how much flexibility, if any, agencies and departments have to create private clouds at the bureau and/or interagency level).

As a cloud storefront, GSA needs to conduct due diligence to establish that public cloud providers, once identified, indeed offer highly efficient, highly scalable (both up and down) usage-based pricing beyond traditional managed services (e.g., by comparing proposed rates against commercial benchmarks). GSA should also work with potential providers to ensure agencies can readily understand service definitions, service levels, terms, conditions, and pricing. These steps will provide transparency to facilitate agencies' ability to compare potential provider pricing against their legacy operations costs—an essential component of building a credible business case for any type of cloud migration. In earlier shared services initiatives, such as financial management, the lack of such standardized information on pricing and service levels during the first few years proved a major impediment to progress, as agencies faced decisions about alternative solutions that were often based on unreliable cost data from potential vendors.

Finally, GSA will need to establish and communicate its own pricing for the cloud-related acquisition assistance services it provides to agencies for the use of schedules.

Summary of Key Observations

Our analysis demonstrates that although cloud computing indeed offers potentially significant savings to federal agencies by reducing their expenditures on server hardware and associated support costs, chief information officers, policymakers, and other interested parties should bear in mind the following practical considerations:

- It will take, on average, 18–24 months for most agencies to redirect funding to support this transition, given the budget process.
- Some up-front investment will be required even for those agencies seeking to take advantage of public cloud options (given the security and privacy concerns described earlier, we believe this group of agencies will be a minority).
- Implementations may take several years, depending on the size of the agency and the complexity of the cloud model it selects (i.e., public, private, or hybrid).
- Once implemented, it could take as long as 4 years before the accumulated savings from agency investments in cloud computing offset the initial investment costs; this timeframe could be longer if implementations are improperly planned or inefficiently executed.

Given these observations, we offer the following recommendations:

- OMB, GSA, and other organizations, such as the National Institute of Standards and Technology

(NIST), should provide timely, well-coordinated support—in the form of necessary standards, guidance, policy decisions, and issue resolution—to ensure agencies have the necessary tools to efficiently plan and carry out migrations to cloud environments. As the length of the migration period increases, the potential economic benefits of the migration decrease.

- OMB and GSA should seek to identify those agencies with the highest near-term IT costs and expedite their migration to the cloud.
- To encourage steady progress, OMB should establish a combination of incentives and disincentives; e.g., consider allowing agencies to retain a small percentage of any savings realized from cloud computing for investments in future initiatives. To monitor progress and heighten transparency and accountability, OMB should incorporate cloud-related metrics into the new government-wide IT dashboard.
- Agencies should consider which of the high-level scenarios described in this paper is best suited to their needs, with the understanding that regardless of the chosen scenario, proper planning and efficient execution are critical success factors from an economic perspective.
- Given the significant impact of scale efficiencies, agencies selecting a private cloud approach should fully explore the potential for interdepartmental and interagency collaboration and investment (consistent with emerging OMB and GSA guidance). This, in effect, leads to the fourth cloud deployment model—the community cloud. A community cloud is a collaboration between private cloud operators to share resources and services.
- Agencies should identify the aspects of their current IT workload that can be transitioned to the cloud in the near term to yield "early wins" to help build momentum and support for the migration to cloud computing.

Cloud computing has received executive backing and offers clear opportunities for agencies to significantly reduce their growing data center and IT hardware expenditures. However, for the government to achieve the savings it envisions, organizations charged with oversight, such as OMB, NIST, and GSA, will have to help drive progress, and departments and agencies will have to carefully select and plan for future cloud scenarios that yield the best tradeoffs among their respective costs, benefits, and risks.

About the Authors

Ted Alford, an Associate at Booz Allen Hamilton, has 20 years of professional experience providing cost and economic analysis support to federal government clients, including the National Security Agency, Department of Defense, Department of Labor, Federal Aviation Administration, and Defense Logistics Agency. He has specifically focused on estimating the costs and benefits and analyzing the economics of information technology projects. Over the years, Mr. Alford has been the lead analyst supporting the development of analyses of alternatives, program office estimates, economic analyses, and cost benefit analyses. In supporting these efforts, he has developed life-cycle cost estimates, estimated quantifiable benefits, analyzed cost and schedule risks, and analyzed justification of investment decisions.

Gwen Morton is a Senior Associate in Booz Allen Hamilton's economic and business analysis e-Government practice. This practice is designed to provide government decision makers the multidimensional perspective required to understand and successfully function in the e-Government environment. The practice's iterative approach combines experience in government business planning with techniques for analyzing and managing e-business ventures and an understanding of the unique challenges and opportunities associated with e-Government. Ms. Morton's major clients include the Department of Agriculture, Social Security Administration, Department of the Interior, and General Services Administration.

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