Preventing E-Government Tragedy Of The Clouds Using System Thinking Methods

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***Abstract*—The purpose of this study is to propose the use of system thinking methods in E-Government systems and system of systems to drive greater efficiencies in the deployment of public cloud services. Qualitative methods such as a systemigram, causal loop analysis, as well as a novel cloud cost reduction model is used to map complexity, display the multidimensional nature of the system, as well as formulate an ontology. The "tragedy of the commons" economic concept is used to orient our research towards the sustainable consumption of digital resources for government agencies. Business and system dynamics concepts are used to both discover as well as propose solutions for the research problem, which is identified as E-Government cloud services efficiency and cost optimization. We conclude with additional ideas to further this research through the use of triangulation and additional quantitative research methods.**

Keywords*—E-Government, E-Governance, Systems thinking, Systems Dynamics, Public cloud.

I. Introduction

State and local governments continue to embrace digital transformation initiatives that provide services and accessibility for both citizens as well as business in their respective jurisdictions. The emergence of E-Government, which is defined as the use of information and communications technology (ICT) to provide public services for government to government (G2G), government to citizen (G2C), and government to business (G2B) has become a shaping force for the use of cloud services [1] [2] [3]. Cloud computing, defined by NIST is "a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction". This new technical consumption model operates similar to a public utility where resources are charged based on the amount of resources used by the agent. As E-governments continue to expand, so does their requirement for cloud computing services to host infrastructure platforms, applications, data repositories, as well as network interfaces [4] [5] [6]. This resource need, however creates a challenge as programs and projects for E-services grow so does the respective budget and spending. Government agencies now see value in digital services and choose to leverage them to deliver positive outcomes for constituents and businesses. This situation of competing priorities as well as consumption can create a modern-day "tragedy of the commons", which is the potential rapid deterioration or complete elimination of a resource due to overly aggressive demand without limitations or constraints [7] [8].

A. Research Questions

Research questions we aspire to answer are, firstly how do we represent the complexity and boundary of the system, its stakeholder interests, as well as multiple interconnections and dimensions? Secondly, how do we define causal relationships of the system to understand both virtuous, vicious, as well as balancing cycles and the effect of time delay. Finally, how can a cloud efficiency model applied to these public cloud resources limit the potential for budgetary overruns and ensure a resilient and sustainable E-Government service?

B. Methods

We leverage a qualitative system thinking method known as a systemigram to represent complexity and system boundaries as well as a causal loop analysis to display the effect system elements have on each other, both reinforcing as well as balancing [9] [10]. Finally, we address governance and the important role it will play in system dynamics to set thresholds and limits by using a novel cost reduction model.

C. Structure

A foundational conceptual understanding of cloud computing is provided in the primer section, followed by a view of the complex E-Government system of interest using a systemigram. Economics of cloud describes how this new computing utility is financially structured, and the unique ways that stakeholders and consumers can interact and consume the vast amount of technical resources. A new model developed for E-Government, provides high-level guidance in the form of capabilities, solutions, and respective outcomes, which we call the "cloud efficiency model" [11]. A Causal loop analysis is an instrument out of system dynamics and is used to display reinforcing behaviors, such as cloud spend and vendor revenue generation as well as balancing factors, such as budgetary constraints. The conclusion discusses ideas to enhance and extend this research effort.

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II. Cloud Computing Primer

Today there are multiple large public cloud technology providers and services used extensively by both private as well as public sector customers [12] [13]. We list three major cloud providers, also known as ”hyperscalers”, as well as some of the most widely used services they host.

Public Cloud providers

- Amazon Web Services (AWS)
- Microsoft Azure Cloud (Azure)
- Google Cloud Platform (GCP)

Public Cloud Prominent Services

- AWS Services
  1) Elastic Compute Cloud (EC2)
  2) Relational Database Service (RDS)
  3) Elastic Container Service (ECS)
- Microsoft Azure Services
  1) Azure Active Directory (AD)
  2) Azure Content Delivery Network (CDN)
  3) Azure Data Factory
- Google Cloud Platform Services
  1) Database Services
  2) Big Data Services
  3) Machine Learning Services

III. E-Government System Complexity

Using a systemigram, we can see in Figure 1 how the mainstay represented in yellow displays primary system nodes, which include government services, operations, employees, and citizens, which are both important and relevant to our narrative. Branching off in red are public cloud services that connect to elements, such as third-party vendors, as well as the information system (IS) budget, which has multiple outflows and only a single inflow.

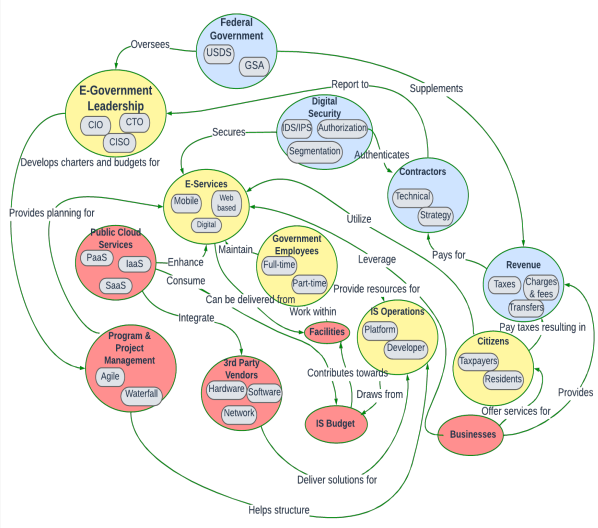

Fig. 1. Systemigram.

In the blue-colored section, we show the interconnections of the federal government, revenue, as well as digital security which in this environment is paramount to the success of the system. As we can see from Figure 1, E-government's use of cloud computing has an inherent complexity in its mission to provide secure, scalable, and resilient E-services to its citizens [14] [15].

IV. Economics of Cloud

The concept of cloud computing is to provide a simplified and consolidated platform hosted off-site that removes much of the operational overhead of traditional private cloud data center technologies. Many private and public sector IS teams are adopting this cloud-hosted model as it allows them to focus on the higher layer applications and remove the need to spend resource cycles with physical equipment maintenance and upgrade processes. This shifting of data center operations, in many cases, removes the need for dedicated operational staff; therefore operational expenditure budgets can be re-appropriated towards greater consumption of compute resources [16].

There are two ways to consume cloud-based services, the first is direct from the cloud provider, and the second is indirect via a third-party integrator. Entities that consume cloud services do so via a subscription that involves a legal contract or ”terms of service” (TOS) that stipulates the rules and guidelines for the consumer. Vendors have multiple ways of selling cloud services, and one of the most popular is under a consumption plan agreement that define how much of a resource will be consumed over a certain period of time. An example is a government organization that signs a three-year multi-million dollar contract with a cloud vendor to use services such as email for their staff. The government agency benefits from the use of this highly scalable email system for its employees, and the cloud vendor receives revenue which is assumed to be allocated to fund ongoing research and development operations, finance, HR, as well as enhancing shareholder value due to its favorable earnings projections.

While this cloud-hosted IS strategy seems to be an advantageous relationship for all parties, there are some caveats to consider. One of the issues with the cloud is its seemingly endless supply of resources for end users of its services. The reality is that physical data centers with compute, network, and storage equipment are still required to host the infrastructure required to deliver cloud services. This means that there is a finite amount of resources from any cloud vendor, some customers have experienced hitting these limits when provisioning additional capacity. This was recently experienced due to pandemic-related supply chain shortages in microprocessors and hardware needed to expand hosted environments [4]. In addition to the constraints possible by cloud providers, government agencies have fixed budgets, and these can shift based on a multitude of factors such as government revenue or alternate priorities. A possible scenario could be the case where a government entity wants to expand its cloud services but cannot due to the hosting costs being greater than the allocated

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budget. The entity could request a budget enhancement or one-time over allocation however, this may take time to obtain requisite approvals or authorization, causing a potential delay [17].

As we have seen in the research, this issue of cloud economics, such as the panacea of cloud, requires careful planning and proper allocation of funds and resources to ensure the long-term effective use of the resources. Shaping forces are all around to turn a well-run environment into a security breach or system down emergency, negatively impacting mission-critical systems [18].

V. Cloud Efficiency Model

With the goal of ensuring the prolonged efficient use of cloud computing resources in E-Government, a novel model is created in Figure 2, which addresses the technical capabilities desired, solutions which can be employed, as well as positive outcomes which help in the conservation of budget. Based on the E-Government service being delivered, one or many of these solutions can be adopted, leading to outcomes that are oriented towards sustainability [19]. The technical capabilities are broad, high level domains spanning the most commonly requested infrastructure components and services. The solution for each respective capability provides more conceptual guidance as opposed to specific solutions. This is due to a rapidly changing landscape of technical solutions constantly entering and leaving the market.

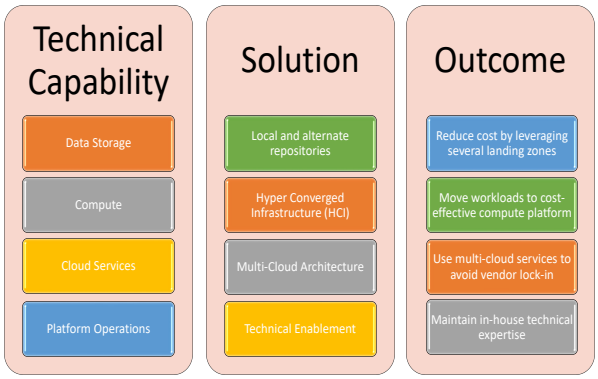

Fig. 2. Cloud Efficiency Model.

The outcome maps to business value and is intended to validate the goal of adopting the solution. Each outcome is directed towards cost efficiency, sustainability, and preservation of resources which can be technological, human, or monetary.

VI. Causal Loop Analysis

To obtain a graphical representation of how E-government spending on cloud computing affects other elements such as cloud vendor revenue, a causal loop diagram is developed [20] [21]. As we see in Figure 3, a reinforcing loop is established by E-government consumption of cloud resources which increases their digital service catalog and offerings. Similarly, as the cloud vendor providing services continues to grow, their offerings and revenue increases in another reinforcing loop. The balancing portion of this analysis comes via the finite E-Government budget that constrains both what is consumed as well as what is offered.

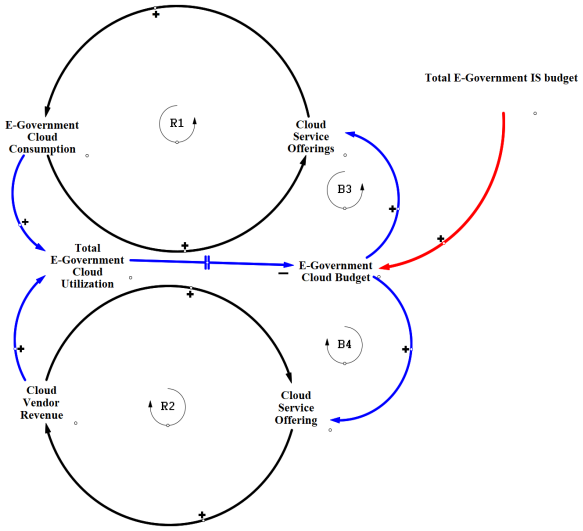

Fig. 3. Causal Loop Analysis.

There is a delay factor which in some cases could prove problematic if the consumption exceeds the budget or if the budget gets cut without timely notice to the operations team, which is provisioning new services. This situation could prove harmful if a sustainable resource management system was not planned for and executed. Also, having proper visibility to the cost of cloud services and discounted rates can help ensure continuity [22] [23].

VII. Conclusion

System thinking methods were employed in this study to analyze how cloud computing impacts E-Government services. First, we utilized the systemigram to map the complex relationship between E-Government agents, vendors, citizens, and the federal government [24]. This revealed different stakeholder interactions and provided insight into possible shaping forces that may impact how these digital services are fulfilled, operated, and delivered. Next, a novel model for E-Government cloud cost reduction was proposed to provide technical leadership with solutions and respective outcomes based on the capability being considered. Leveraged properly and given due consideration, these solutions may have a lasting impact on future costs associated with consumption of cloud services. Finally a causal loop analysis was developed to show the interconnections between E-Government use of cloud, reinforcing vendor revenue streams, as well as how budget constraints become balancing factors in this flow of resource and funds. This study lacks a complete quantitative analysis component with data that would have enhanced our models, specifically our causal loop. An idea for further study and enhancement of the contribution would be to gather data related to government spending on cloud computing platforms and use mathematical models as a triangulation technique

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to complement the qualitative components. Cloud technology will continue to grow in government, therefore, being able to find sustainable and responsible ways to ensure its prolonged use would provide value to those who are tasked with its operation [3].

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