# C2TP: A Service Model for Cloud

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***Abstract*** **- The notion of cloud computing capability is gathering momentum rapidly. However, the governance and enterprise architecture to obtain repeatable, scalable and secure business outcomes from cloud computing is still greatly undefined. There is very little research explored to define a framework that not only considers financial motivations, but also business initiatives, IT governance structures, IT operational control structures and technical architecture requirements to evaluate the benefits regarding cloud investment. We are proposing a novel model to address this. This model can be leveraged by an organization to evaluate the "tipping point" where the organization can make an informative decision to embrace cloud computing at the expense of on-premise hosting options. The authors refer to this model as Cloud Computing Tipping Point (C2TP) model. The model is a service centric framework created by mapping cloud computing attributes with industry best practices such as ValIT, Control Objectives for Information and related Technology (COBIT) and Information Technology Infrastructure Library (ITIL). This paper discusses the C2TP model in detail with its findings.**

***Keywords - Cloud computing Tipping Point; C2TP; Cloud readiness model; CTPXML; Cloud artifact; Cloud taxonomy***

## I. INTRODUCTION

Merrill Lynch research estimated cloud computing as a "$160 billion addressable market opportunity, including $95 billion in business productivity applications, and another $65 billion in online advertising" [11]. There are several industry vendors (e.g., Amazon, Google, Microsoft, Sun, Salesforce, HP, etc.) attempting to capitalize on this market opportunity. Academic research community has also taken a keen interest in creating frameworks such as Virtual Workspaces [18], OpenNebula [22], Eucalyptus [10],[39] and Aneka [5] to address this opportunity. According to Buyya & Yeo [5], the hype about cloud computing is getting realized in the form of real world solutions. They continue to elaborate by focusing on computation power as the 5th utility on top of water, electricity, gas and telephony [6]. This computing utility will provide basic computation requirements for essential every day needs similar to the other four utilities stated above. They identify cloud computing is one of the paradigms that could realize this vision [6].

An ICT organization will reach a "cross road" or an "equilibrium" where the organization is required to make a conscious decision to either enhance the existing *on premise* investment or procure IT capability via cloud computing providers [26]. The popularity of cloud offerings are primarily driven by the financial benefits gained by organizations in comparison to *on premise* investments. Buyya, Pandey & Vecchiola [4] proposed a market oriented cloud computing architecture leveraging "Cloudbus" toolkit. The Cloudbus architecture addresses simulations, policies and algorithms to facilitate the cloud marketplace. Lenk et al. [20] created a general framework that targets transitioning from existing systems to cloud offerings. This framework primarily focuses on the financial advantages of the cloud platforms. Both of these capabilities do not address a model that an organization can leverage to evaluate organization's business initiatives, existing IT investment and existing IT control structures to determine the equilibrium (or a "tipping point") for cloud computing investment. This information is vital to evaluate the decision to either migrate to the cloud or expand on existing investment for an organization.

This paper attempts to address this research gap. The focus of this paper is to demonstrate Cloud Computing Tipping Point (C2TP) model that an ICT organization can leverage to evaluate the future benefits or limitations. The authors developed the following approach to create the C2TP model as detailed in Figure 1.

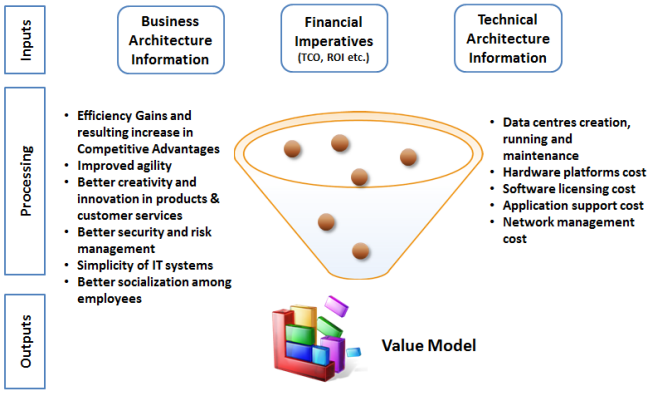


Figure 1. C2TP model inputs, processing and outputs

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The authors have leveraged multiple case studies representing both enterprises and small to medium enterprises to investigate the relevant attributes for the perceived model. The model primarily focuses on organization's business architecture information, financial viability information and technical architecture information [27]. They are described as "inputs" of the model in Figure 1. The model captures many attributes that represent the above focus areas. This is illustrated as "processing" in Figure 1. These subject areas are discussed in detail in the next section. They are analyzed and evaluated to generate multiple measurements and services. Figure 1 illustrates these measurements and services as "outputs". These measurements and services are described in sections II and IV. These services can be leveraged to provide guidance regarding the "readiness" of the organization to embrace or decline on cloud offerings. Section III of this paper describes the details of an artifact designed to evaluate and capture findings of C2TP model. Section V will detail the findings, conclusions, future work and related work.

## II. C2TP MODEL

The C2TP model will enable organizations with the knowledge to invest in future strategic decisions regarding cloud computing investment. The model will evaluate financial, business and technical data to derive a conclusion whether the organization will benefit from investing in cloud computing or extend their investment in *on premise* capability. This is an important toolset that can be leveraged by the industry and will actively contribute to cloud computing enterprise architecture. The following Figure 2 illustrates components of C2TP model.

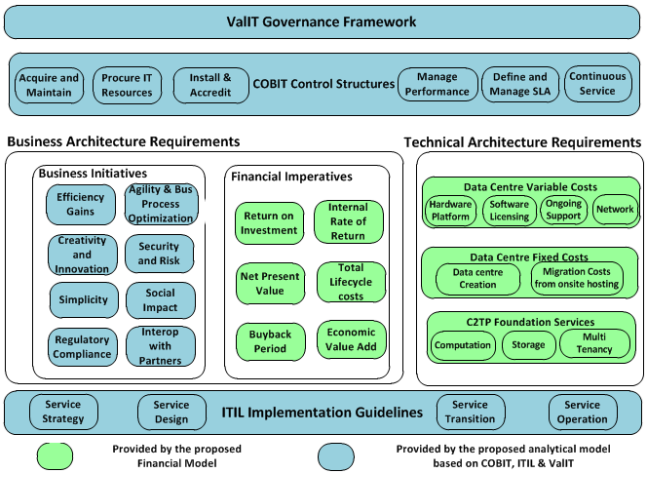


Figure 2. C2TP : Cloud computing Tipping Point Model

The authors explored whether they could use industry best practices of Control Objectives for Information and related Technology (COBIT) [7] and Information Technology Infrastructure Library (ITIL) [14] as a base framework to define the attributes for the Cloud Computing Tipping Point model. Lainhart [19] described COBIT as a "methodology for managing and controlling Information. It also controls Information Technology risks and vulnerabilities". IT Infrastructure Library (ITIL) is a set of industry best practices published by British Office of Government Commerce (OGC) [14]. It comprises of operational framework details that includes industry best practices, standard operating procedures and technical operating procedures. The authors concluded that the high usage of these frameworks in the industry and their proven control structures provide a solid foundation for the C2TP model. The primary attributes planned for the model are,

a) Better risk management and information security
b) Better software development life cycle management
c) Better business continuity
d) Excellent capacity and availability management
e) Low cost operations
f) Shorter implementation life cycles of IT systems and applications
g) Enhanced service levels
h) Higher uptime

The authors also concluded that some of the long term strategic objectives (e.g., value management, optimizing internal rate of return etc.) of a Cloud solution are not addressed by COBIT and ITIL control structures [29]. Therefore, they have leveraged ValIT [36] model to address these gaps. ValIT addresses assumptions, costs, risks and outcomes related to a balanced portfolio of IT-enabled business investments. It also provides benchmarking capability and allows enterprises to exchange experiences on best practices for value management [36]. Therefore, the authors have decided to leverage COBIT, ITIL and ValIT to provide the governance framework for Cloud Computing Tipping Point model. The authors have created key metrics to measure the outcome of the model [28]. They are,

- C2TP Financial Model metric.
- C2TP Business Initiatives Index.
- C2TP Operational Governance Index.
- C2TP Readiness Index.

### A. C2TP Financial Model

The C2TP financial model analyses the fixed and variables costs of migrating and sustaining cloud platform architecture. The financial model currently accommodates the following costs. These are staff costs, help desk costs, server maintenance costs, server replacement costs, data center environment costs, software licensing costs, software maintenance costs, networking costs, storage costs, migration costs, centralization costs, journaling costs, training costs, archiving infrastructure costs, archiving content costs, backup and recovery costs, disaster recovery costs, support consultancy costs and cost of Investment (interest on borrowed funds to facilitate the investment). Future work on this base framework can expand these criteria further.

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The model analyses the above costs for *on premise* IT investment and will compare it against the cloud alternative capability. The model evaluates the financial position of the *on premise* investment and cloud offerings by referring the following equation. Note that "n" is a positive integer and "N" is the total number of financial costs.

$$\sum_{n=0}^{N}(Cost_{Cloud}) \; < \; \sum_{n=0}^{N}(Cost_{On\ Premise})$$

An organization is financially in a better position if the cloud offerings investment is less than the *on premise* investment.

### B. C2TP Business Initiatives Index

C2TP business initiatives index evaluates the organization's eagerness and ability to embrace cloud computing as a mechanism to gain completive advantage over their peers. The business initiative attributes of the model are,

- Efficiency gains
- Agility
- Creativity and Innovation
- IT Security issues
- Risk Management
- Simplicity of capability development and management
- Business process optimization
- Social impact to the employees
- Regulatory compliance
- Interoperability with partner organizations.

The C2TP model gathers the organization's perceptions and priorities regarding the above subject areas. This information is gathered by answering series of questions to evaluate the organization's perspective of these business initiatives under the *on premise* model and alternative cloud computing capability. These business questions leverage ValIT, COBIT and ITIL key subject areas. The total of *on premise* business initiatives are collected together as "On Premise Business Initiatives index". The total of cloud business initiatives are collected together as "Cloud Business Initiatives Index". In order to move to the cloud, the Cloud Business Initiatives Index requires to be greater than the On premise Business Initiatives index as described below. Note that "n" is a positive integer and "N" is the total number of business initiative measures. (Note – Business Initiatives Index is abbreviated as "BII")

$$BII_{\ Cloud} \; = \sum_{n=0}^{N}(Business\ measure_{\ Cloud})$$

$$BII_{\ On\ Premise} \; = \sum_{n=0}^{N}(Business\ measure_{\ On\ Premise})$$

$$BII_{\ Cloud} \quad > \quad BII_{\ On\ Premise}$$

### C. C2TP Operational governance Index.

This index attempts to compare the organization IT governance and control objectives under the *on premise* and cloud computing models. This measure is vital to ensure the organizations future IT platform (regardless of *on premise* or cloud computing) is operating as efficiently as possible. COBIT and ITIL provides extensive capability in industry implementations for similar requirements. The authors have evaluated these industry best practices extensively. Therefore, the C2TP model is influenced by COBIT and ITIL control structures to address some of the key capabilities as described below.

*1) Acquire and Maintain Application Software*

The key focus areas under this model are,

- Which model is more efficient in procuring software?
- Which model attracts the best licensing costs arrangement for the organization?
- Which model manages the licensing costs better? (e.g., better tools are available for management and transparency)
- Which model provides more efficient application maintenance?
- Under which model is application maintenance financially attractive?

*2) Procure IT Resources*

The key focus areas under this model are,

- Which model provides the procurement efficiencies? (i.e., less time to procure software)
- Under which model is it easier to secure IT resources that are skilled to develop IT capability?
- Which model offers cheaper to find IT resources?
- Which model offers efficient project management?

*3) Acquire and Maintain Technology Infrastructure.*

The key focus areas under this model are,

- Which model offers simpler procurement process to acquire hardware resources?
- Which model offers lower infrastructure costs for the organization?
- Which model offers better hardware infrastructure optimization?
- Which model offers better tools to address disaster recovery functions?
- Which offers better toolset to manage the organization's infrastructure?

*4) Manage Performance and Capacity*

The key focus areas under this model are,

- Which model offers better performance tools set to monitor hosted applications?
- Which model offers better performance tools set to manage hosted applications?
- Which model provides easier access to increase or decrease capacity?

*5) Define and Manage Service Level*

The key focus areas under this model are,

- Which model offers better Service Level Agreements (SLA) for organization needs?
- Which model offers liability measures (from providers) in case of lack or interruption of service or data?
- Which model offers clear 'pay per view' cost structure for services consumed?

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*6) Ensure Continuous Service*

The key focus areas under this model are,

- Which model offers better availability of data?
- Which model offers better availability of critical services?
- Which model ensures integrity of data?
- Which model ensures integrity of critical services?
- Which model ensures confidentiality of corporate data?
- Which model secures organization from Denial of Service attacks?

C2TP model evaluates these subject areas by engaging with the target organization with a series of workshops, questions and answers sessions and presentations. The interactions with the organizations and the organization's responses are recorded in the C2TP artifact tool. This tool and its functionality will be described in section III. The organization evaluates its *on premise* business case against the cloud computing alternative under the C2TP model. The C2TP model proceeds to accumulate this information and derives Operational Governance Index for *on premise* and cloud computing alternatives. Then the model compares the two indexes to analyze the suitability of each model. The Operational Governance Index of cloud computing should be greater than the Operation Governance Index of *on premise* model in order for an organization to benefit from cloud computing offerings. The equations to obtain this decision are demonstrated below. Note that "*n*" is a positive integer and "*N*" is the total number of operational governance measures. (Note - Operational Governance Index is abbreviated as "OGI".)

$$OGI_{Cloud} = \sum_{n=0}^{N} (Operational\ Gov.\ measure_{Cloud})$$

$$OGI_{On\ Premise} = \sum_{n=0}^{N} (Operational\ Gov.\ measure_{On\ Premise})$$

$$OGI_{Cloud} > OGI_{On\ Premise}$$

### D. C2TP Readiness Index.

C2TP model readiness index is the end result of the evaluation. The readiness index will elaborate the organization's "readiness" to embrace cloud computing or whether it has reached the "tipping point" to invest in cloud computing offerings. The Readiness Index is derived by aggregating the previous discussed indexes. The authors believes the C2TP readiness index and all the other indexes needs to be positive to conclusively decide that the organizations have reached the "tipping point" to invest in cloud computing offerings. The following illustrates this equation.

*C2TP Readiness Index =*
*Financial Model + Business Initiatives Index + Operational Governance Index*

The authors developed an artifact to demonstrate this model and to evaluate its capability extensively. This conclusion of C2TP Readiness Index was confirmed by the findings of the artifact.

## III. C2TP ARTIFACT

This section discusses the Cloud Computing Tipping Point artifact that was designed and developed to evaluate and captures the information in relation to C2TP model.

### A. Research method – Artifact building

Artifact design is an iterative process. March and Smith believes that the search for the best, or optimal, design is often intractable for realistic information systems problems [23]. Simon [32] describes the nature of the design process as a Generate and Test Cycle. According to Simon, we would generate research material and will evolve to new material when we apply testing scenarios. The authors have followed this process numerous times to create the artifact for C2TP model. March and Smith [23] proposed 4 general outputs for design research. They are constructs, models, methods, and instantiations. The C2TP model addresses all 4 of these outputs.

- Constructs are defined by March and Smith [23] as conceptual vocabulary of problems and solution domains. This is addressed by defining extensive conceptual architecture of the C2TP artifact. It breaks down the conceptual architecture to multiple layers (i.e., presentation, business logic and database) and clearly defines each layer's responsibility.
- A model is a set of propositions or statements expressing relationship among constructs [23]. The artifact addresses this requirement by extensive set of Unified Mark-up Language (UML) constructs. They are outputs such as entity relationship diagrams and class diagrams.
- The method is a set of steps used to perform a task [23]. The artifact leverages UML modeling techniques such as use cases and sequence diagrams to address this.
- March and Smith [23] defines instantiations as "operationalize constructs, models and methods. The eventual instantiation of the research is a web site that accumulates all the information regarding the C2TP model.

### B. Solution Architecture for the model

The C2TP conceptual architecture is based on three tier architecture model. The three tiers are Presentation, Business Logic and Database. There are also several "cross cutting" components of the architecture including security, common integration methods and a library of components that addresses instrumentation, auditing, logging, tracing, caching and validation. The authors have created a specific taxonomy to share C2TP model information. This taxonomy is referred to as Cloud Tipping Point Markup Language (CTPXML) [29]. CTPXML is a well formed communication structure specifically designed for C2TP model. The primary objective of CTPXML is to exchange information between C2TP model and its consumers in a scalable and secure environment. The consumers can be number of entities. They

are web browsers, mobile phones, desktop applications or intelligent agents [30].

Presentation layer essentially consists of user experience layer and self-service channel to expose the C2TP model capability. The self-service channel will provide the ability to expose a "service view" of C2TP selected applications to be consumed by external service providers and 3rd parties. The Self Service Channel will host scalable and reliable services that will allow other organizations to build their own applications that leverage C2TP data. However, the application creation and maintenance will be the sole responsibility of the 3rd party organization. The following services will be exposed via these mechanisms that are built on top of the "service agents" that technology platform provides [30].

- C2TP Financial Model Service
- C2TP Business Initiatives Index service
- C2TP Operational Governance Index service
- C2TP Readiness Index service

C2TP Business Logic layer accommodates both in-host and cross-host capabilities. The in-process model supports the web user, mobile user and potential desktop forms application functionality. The in-process model enables memory caching and will provide speedy access to data. The services interface provides a scalable standard interfaces for the Self Service Channel. This layer will provide the proxies or agents that facilitate the plumbing code for the service layer. It also leverages standard service contracts, message contracts, data contracts and fault contracts to communicate to presentation layer. The orchestration layer of the business logic layer is a key capability. The orchestration layer will route client requests to the relevant business components. The orchestration layer coordinates (and in some cases aggregates) data communications between business components and necessary integration components. This layer will also provide framework level support for the following,

- Validation capability – these components provide business level validations (e.g., valid post code) and developer support (e.g., regular expressions to validate email address)
- Business rules and business objects – The business logic and the associated business rules are hosted in these objects.
- The necessary workflow rules and components.
- Client message inspector – This component evaluates the user's authorization credentials to execute the business functionality.
- Parameter inspector – This component will inspect the parameters being provided to the business layer by the presentation layer.

The database solution architecture supports necessary table structures and integration connectors. The database design will follow the 3rd normal form and there are small data marts created for user and administrator reports.

### C. Service enablement of C2TP model

SOA is a software architecture that is designed around loosely coupled software components called services, which can be orchestrated to improve business agility [8]. Vouk [37] defines SOA as delivery of an integrated and orchestrated suite of functions to an end-user through composition of both loosely and tightly coupled functions, or often networkbased services. As defined by W3C, services provide functionality at the application and business levels of granularity using widely applied standards [13] . A conceptual SOA metamodel to enable business capability was demostared by Emig et al [9] and Henkal & Zdravkovic [12]. This SOA metamodel is leveraged to build the C2TP artifact that can seemlessly intercat with 3rd party compoments or intelligent agents to share information generated by the C2TP model.

## IV. RESULTS AND FINDINGS

The proposed model has been validated with results from several organizations with a cross-section of business models. Due to the recent global financial crisis and volatility of the global markets, the organizations were quite keen to investigate technology options that give them a competitor advantage over their competitors. Therefore, C2TP model was viewed as a timely development to assist with their evaluation for cloud computing options.

'One on one' interviews and workshops were the primary mechanisms of collecting data and evaluating C2TP model with target organizations. The collected information was entered into the C2TP artifact to process the results. The C2TP artifact produced the financial model and the relevant indexes to evaluate the cloud computing suitability. The results were member checked [21] with the participants. Member checking was performed both during the interview (or workshop) process and at the conclusion phase. Interviewer corroboration [21] was also leveraged as a validation technique to ensure the quality of results. Negative case analysis [34] provided a valuable toolset to refine the model further in some cases. The paper categorized these findings under two categories to address necessary cross sections of the IT industry. They are as enterprise clients and small or medium enterprise clients.

### A. Validation of Enterprise clients

Experiment 1 - C2TP model was evaluated by representatives of a global consulting company that has in excess of 80,000 employees. The organization is a mature CMMI level 5 accredited IT services provider. The representatives' motivations were to analyze the cloud email hosting benefits of transferring their *on premise* capability to cloud platform. They were interesting in leveraging both Infrastructure as a service and software as a service cloud offerings. They leveraged the C2TP model to comprehensively analyze their requirements. Here are the results.

- The model clearly identified the financial benefits leveraging the formulae discussed earlier. The C2TP Financial readiness Index was positive.

- The C2TP business Initiatives index was also positive. This supported the conclusion of the organization business initiatives are in synergy with the cloud platform offerings.
- C2TP Operational Governance Index was positive. The organization's accreditation of CMMI level 5 had ensured structured processes to address management and governance issues. Therefore, the organization could effectively transition their *on premise* email hosting environment to cloud computing offering with minimum number of business interruptions.
- The C2TP model concluded that the C2TP Readiness Index was positive in light of all the other indexes were positive. Therefore, the C2TP model endorsed the organizations strategy to migrate their email hosting system to cloud platform and start leveraging the benefits of the cloud architecture.

The participants provided valuable feedback as part of member checking to enhance the C2TP model. They have indicated the value of benchmarking their findings with similar organizations to further understand the competitor advantages and limitations. They have highlighted that a rich set of historical data that focuses on their industry does add substantial value to the existing C2TP model. This important discovery was corroborated by other interviewers subsequently.

Experiment 2 - The 2nd enterprise company is a global supplier of security hardware to financial industry and government agencies. They have close to 20,000 global employees. The company representatives' interest was to leverage the C2TP model to evaluate their "Next generation desktop" project. This is a platform rationalization project viewed as an opportunity to provide a solution for their existing aging desktop platform. This platform as a service project also attempts to provide a single environment for the company's newly acquired subsidiaries to work together and to be integrated into their global headquarters. Here are the findings

- The C2TP Financial Readiness Index was positive indicating the financial benefits of rationalizing their platform with cloud platform offerings.
- The C2TP Business Initiatives Index was negative. The company subsidiaries operated as independent entities in all its geographies. Therefore, their business initiatives were influenced heavily by demographic circumstances and were not centrally managed. This was the outcome of several acquisitions and mergers over the years. Unfortunately, the IT environment integration wasn't a priority in these acquisitions and mergers. The objective of the "Next generation desktop" was to provide a unified desktop solution globally. However, the representatives could not agree on the unified set of business initiatives that was driving the project.
- C2TP Operational Governance Index was negative. Due to mergers and acquisitions, there were substantial differences between the IT maturities for IT teams representing different geographies. This led to the conclusion that they need to create a unified IT platform and a governance framework at the global headquarters level before they investigate migrating capability to the cloud. It was noted that this global platform could be viewed as a Cloud offering. However, the representative did conclude there are sensitive data (as a result of their security operations) that they were not planning to host on the cloud offering. They concluded to consolidate all the IT teams and create governance framework. This governance framework will address the issue of sensitive data and investigate leveraging cloud computing for their non-core activities.
- Due to the C2TP Business Initiatives index and C2TP Operational governance index being negative, it was concluded that the C2TP Readiness Index was negative. Therefore, it was concluded that the organization haven't reached the "tipping point" to invest in cloud offerings.
- The conclusion was to enhance their existing invest in on premise offering and enhance the maturity of the organization till it reaches a point where they can revisit the cloud computing value proposition.

The paper leveraged negative case analysis validation technique to refine the model with this particular experiment. The initial data from the C2TP model did not corroborate with the interview findings. Further analysis led to the revision of the model attributes and introducing a "weightings" system for the calculations to reflect these special circumstances.

### *B. Validation of SME clients*

Experiment 3 - The model was evaluated by an Australian consulting company that specializes in collaboration and portal development capability. This company has close to 20 employees. They specialize in collaboration toolset for financial and manufacturing sector. The company was having difficulty to scale their current *on premise* infrastructure platform to facilitate its growing demand. They also noticed high seasonal demand for Collaboration capability towards the start of the financial year by their financial industry clients. The company was having difficulty to justify the additional costs to cater small window during seasonal spikes and leave the resource idle for rest of the year. They were keen to leverage the C2TP model to explore their options and evaluate their readiness to acquire cloud computing capability. Here are the results,

- Positive C2TP Financial Model for the company elaborating the advantages of moving to a cloud provider to facilitate the seasonal spikes in lieu of acquiring new *on premise* infrastructure.
- Due to the small nature of the company and mature ITIL process in place, the C2TP Operational Governance Index was positive.
- Their business Initiatives index was also positive indicating their suitability to migrate to the cloud platform.

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- The C2TP readiness index was positive due to the feedback from C2TP Financial Model, Business Initiatives Index and Operational Governance Index

Member checking and interviewer corroboration were leveraged as validation techniques for this experiment. The organization was keen to leverage C2TP model to investigate sharing CTPXML information with their partner organizations and clients.

Experiment 4 - The 2nd SME participant organization specializes in residential and commercial imagery for product catalogues. This is a small organization with 5 employees. The major challenge was to manage their digital library and keep up to date with technology advancements and security considerations. They were interested in evaluating both platform as a service and software as a service offering to meet their growing demand. They have been leveraging their *on premise* platform for number of years. However, due to increased storage needs, image processing and bandwidth needs, they were finding it difficult to extend their existing infrastructure and justify the extra costs. Therefore, they were keen to evaluate the C2TP model to obtain guidance to make decisions on investing on cloud offerings

- The C2TP Financial Model was positive indicating they were financially in a better position due to their move to the cloud offerings.
- The C2TP business Initiatives Index was also positive indicating that the business models of the company or the business initiatives are not adversely affected by transferring their capabilities to the cloud. They also noticed that cloud offering will significantly reduce their capital expenditure and transfer costs to the "operating budget".
- C2TP Operational Governance Index was positive. The company benefitted from its small size and was able to be agile and improve its process. Therefore, they had sufficient control structures and governance model to successfully migrate to the cloud platform with little process alterations.
- Due to positive feedback from C2TP Financial Model, C2TP Business Initiatives Index and C2TP Operational Governance index, the C2TP Readiness Index was positive. The conclusion was that the organization has the capability and the motivations to successfully migrate to could platform under the C2TP evaluation.

These 4 experiments have addressed both enterprise and small to enterprise organizations to obtain a good cross section of the IT industry. The experiments also addressed variations of size, number of employees, industry focus and multiple geographical locations. C2TP model was leveraged by all 4 experiments successfully with proven validation techniques such as member checking, interview corroboration and negative case analysis. Therefore, the C2TP model has assisted in our research goal to create a model that provides strategic guidance to organizations to evaluate future cloud investments in comparison with *on premise* investment.

## V. CONCLUSION AND FUTURE WORK

### A. Summary of Contributions

The primary contribution of the research is the Cloud Computing Tipping Point (C2TP) model and the artifact to demonstrate its capability. This model will assist organizations to evaluate the "tipping point" whether the organization can either embrace the cloud offerings or enhance their investment in *on premise* IT capability. This model provides a comprehensive structure by leveraging proven financial indicators and industry best practices (i.e., COBIT, ITIL and ValIT). This model addresses a timely need in the industry to create a framework to provide guidance to organizations to evaluate the benefits and limitations of embracing the cloud platform. The current literature and the industry momentum are driven purely by the financial comparisons of *on premise* cost versus cloud computing costs. There is no model available that analyses not only the financials, but also the organization core business initiatives, its existing IT capability control structures and the suitability of the organizations existing IT governance processes in relation to cloud computing. These selection criteria have the same weight as the financial information for organizations

These organizations are aware of the complexities of IT projects. The complexity of these IT projects will further enhance if they include new cloud capability that the organization cannot manage or govern in a scalable and predictable fashion. These organizations also need to mitigate the risk of an external cloud provider having access to their business information. Does the cloud platform offer better "value for money" under these circumstances? Or does the organization conclude the organization's intellectual property information is too sensitive to share on the cloud? Unfortunately, there is no model available to address these concerns currently. The authors believe in a set of minimum criteria or checklist items for organizations to evaluate to determine their cloud readiness. Therefore, the authors believe the C2TP model provides a comprehensive evaluation criterion to address this growing need in the industry. The model provides feedback to an organization on its cloud readiness by factoring in the financials and other key business factors. Therefore, this model enhances the academic body of knowledge in relation to cloud enterprise architecture.

The cloud infrastructure is primarily built using virtualization technologies comprising of hypervisors running on a large number of parallel servers operating in distributed networking environment. The major hosting providers have also launched application programming interfaces for development of cloud friendly programs that can be run in Software as a Service mode. The current hosting providers have kept the backend architectures proprietary and hence there is a risk of the applications getting tied to specific cloud computing environments. The current researchers feel a need for standard cloud infrastructure and an enterprise model that all hosting providers should follow in order to ensure openness of the system from customer perspective. The authors share these

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sentiments and shall contribute to such an open architecture model supporting the empirical generalizations being attempted by the current researchers. The C2TP model will contribute and enhance enterprise architecture of cloud computing as a result of this research.

This paper also analyses the synergy between the industry best practices (i.e., COBIT, ITIL and ValIT) and how they can be coupled together to create an academic model. This academic model then is tested and proven to be effective by referring to the previous section. Selected components of these industry best practices are indirectly peer reviewed and analyzed in academic context. This enhances the 'body of knowledge' of academic empirical studies based on these industry best practices. This will enhance credibility and wider acceptance in academia for these industry best practices for academics to be leveraged in the future.

The CTPXML taxonomy is another contributor as a result of this research. The CTPXML taxonomy is primarily designed as the communication mechanism to share data between C2TP model and its consumers. The taxonomy is based on well-formed XML standards and will follow Web Service Basic Profile standards to ensure interoperability between heterogeneous platforms. The current taxonomy addresses the C2TP model information, security credentials, infrastructure information and transport information. The security, transport and infrastructure information is kept to minimum due to the focus of the C2TP model information. The authors believe these areas will be a prime candidate for future work. The CTPXML taxonomy can be leveraged by multiple clients to render the C2TP information seamlessly to their preferred presentation medium.

### B. Future Work

C2TP model has undergone several iterations already. The model is also evaluated with enterprise and SME organizations as we discussed earlier. The findings of these evaluations were very positive. The findings also shed some light regarding the further enhancements to the model that can be classified as future work.

#### 1) Expanding the initial design of the C2TP artifact

Currently the weighting of the attributes in Business Initiatives Index and Organizational Governance Index are equal. Therefore, each attribute is weighted evenly. The SME case study on enterprise global manufacturing company and similar ones have indicated that this position can be enhanced with a specialized weighting system in the future. This is to reflect that some organizations work in specialized industries with specialized business motivations. Hence they are bias towards certain attributes. For an example, a firm that specializes in Defense IT security has greater dependency on security and risk management attributes. Therefore, enhanced focus should be allocated to some attributes to reflect these industry specific circumstances. Significant industry benchmarking needs to be conducted initially to revise the weighing structure.

Bateman and Wood [2] argues that cloud computing promotes "Green IT" as long as location of hardware and storage premises leverage renewable energy. According to Bajgoric [1] and Vykiukal, Wolf & Beck [38], cloud computing indirectly reduces greenhouse gases and CO2 emissions. Issa, Chang and Issa [16] have proposed a PESTEL (i.e., Political, Economic, Social, Technological, Environmental and Legal) evaluation regarding cloud computing sustainability. The authors believe future expansions of the C2TP model should evaluate these current research developments.

#### 2) A multi agent design & implementation architecture

The CPXML Taxonomy and service design of C2TP model can be leveraged by intelligent multi agents to capture process and evaluate information. This can be achieved by multiple intelligent agents working in synergy by communicating with other intelligent agents adhering to specific rule set. The agents can control the flow of information and manage the constant communications between the nodes. The agents can also be mobilized to address different components of the model and use complex algorithms to analyze developing situation in light of variable user input. The intelligent agents will be able adapt to information provided by the user and propose different metrics to evaluate the cloud suitability under these circumstances. Here are some of the opportunities leveraging current research

- Son and Sim [33] are creating a multi-issue negotiation mechanism for cloud service reservations. These agents will be able to negotiate price and time slot among cloud partners. The C2TP agents will be able to communicate with these intelligent agents to conduct and report on these negotiations.
- Kang and Sim [17] are creating a cloud ontology and agent based cloud search engine referred to as "Cloudle". It is specifically designed to find cloud services over the internet. C2TP agents will be able to provide valuable information to expand this ontology and benefit form Cloudle search engine to locate complimentary cloud services.

#### 3) Industry benchmarking for C2TP model

As discussed earlier, industry benchmarking has been identified as a key focus area for future work. It is expected that the C2TP model will evolve and refine according to the industry benchmarking feedback. Benchmarking and wide acceptance of the model will assist to refine the weighting system for attributes of the model. The C2TP model will evolve to comprise core competencies and will accumulate industry specific competencies as the result of the benchmarking activities. The participant organization will obtain richer and more competitive data analysis in their C2TP evaluation. Lenk and Nimis et al [20] has introduced an open framework to migrate the pre-existing cluster and grid computing capability to cloud computing. C2TP can leverage this framework to provide a future roadmap with the benchmark information as an implementation guide. This will provide both strategic and tactical information to the C2TP model consumer.

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*4) Enhancement of CTPXML taxonomy*

The CPXML Taxonomy and service design of C2TP model can be leveraged by intelligent multi agents to capture, process and evaluate information. This can be achieved by multiple intelligent agents working in synergy by communicating with other intelligent agents adhering to specific rule set. An open implementation model has been proposed based on standard SOAP, UDDI and WSDL protocols. These standard protocols can be leveraged by intelligent multi agents to manage the C2TP evaluation process. The agents can control the flow of information and manage the constant communications between the nodes. The agents can also be mobilized to addresses different components of the model and use complex algorithms to analyze developing situation in light of variable user input. The intelligent agents will be able adapt to information provided by the user and propose different metrics to evaluate the cloud suitability under these circumstances.

The CTPXML taxonomy is expected to evolve with each new revision of the model. The benchmarking and refining of the model will introduce new taxonomy changes that need to be reflected in the communication with the model consumers through intelligent agents. It is also expected that the current model's security and transport capabilities will be enhanced. This will also result in some adaptation of the CTPXML taxonomy.

### C. Related Work

Cloud computing popularity has prompted several academic and industry initiatives to explore the capabilities and enhancements in cloud computing. The value proposition of cloud computing in comparison with *on premise* investments is one of the key research areas. There are several initiatives to specifically address the economic viability of the cloud investment. They are primarily driven by industry vendors to promote their offerings. Cloud ROI Framework [15] and Azure ROI calculator [24] are two examples of this initiative.

There are several academic initiatives investigating key business model aspects of cloud computing. Buyya, Pandey & Vecchiola [4] proposed a market oriented architecture for cloud computing. This is a continuation of Buyya and Yeo et al. [6] attempt to introduce cloud economic model. Lenk et al [20] created a general framework that targets transition of existing systems to cloud platforms. Sun et al [35] discussed a SLA based model to facilitate financial services infrastructure. Brebner and Liu [3] compared various vendor offerings such as Google App Engine, Amazon EC2, and Microsoft Azure to provide guidance on cost, application performance (and limitations) for different deployment scenarios.

These academic initiatives are parallel related work to C2TP. However, all these initiatives are focused on financial benefits an organization can derive from cloud computing. Therefore, the C2TP model offers a unique research value by including organization's business initiatives, governance processes, existing control structures and technical architecture attributes on top of the financial imperatives. The paper believes the C2TP model contributes to the cloud computing enterprise architecture and will be leveraged by future academic research endeavors.

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