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Title	Innovating in the Cloud
Author(s)	Clohessy, Trevor; Acton, Thomas; Coughlan, Chris
Publication Date	2013
Publication Information	Clohessy, Trevor; Acton, Thomas; Coughlan, Chris (2013) 'Innovating in the Cloud'. International Journal of Innovations in Business, 2 (1):29-41.
Publisher	Center for Innovations in Business & Management Practice
Link to publisher's version	<a href="http://www.cibmp.org/journals/index.php/ijib/article/view/40">http://www.cibmp.org/journals/index.php/ijib/article/view/40</a>
Item record	<a href="http://hdl.handle.net/10379/7210">http://hdl.handle.net/10379/7210</a>

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# Innovating in the Cloud

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## **Abstract**

Cloud computing may offer a new architecture in fostering innovation. This paper describes salient issues in cloud computing capable of facilitating innovation in organisations. Focusing on the potential value to organisations of cloud computing, in this paper we outline particular aspects of contemporary concern to organisations innovating for competitive advantage. Using a lens of innovation-enabling and routes to competitive advantage, we focus on and identify aspects of cloud computing capable of offering value to organisations without invasive surgery to their operational processes or strategic direction. This paper indicates value in particular cloud services, with dependencies on implementation and coupling to strategic goals. Further, indications support organisational concerns on security, and other concerns typically prevalent in applications outsourcing. The paper concludes with recommendations regarding initial traversal of cloud-based potential for organisations intent on paddling rather than diving into cloud computing as a vehicle for innovation.

**Keywords:** cloud computing, innovation, competitive advantage

## **Introduction**

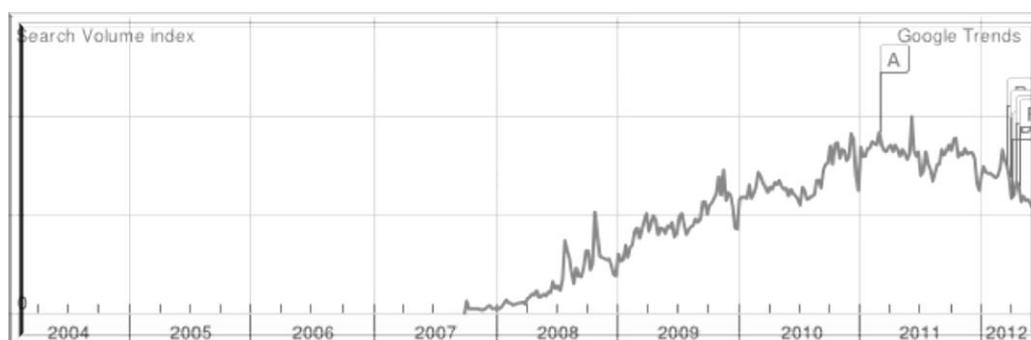
The holy grail of the attainment of sustained competitive advantage has long featured in business strategy and has been heavily discussed over the last few decades in both the management and information systems literature bases, with emerging technologies and

computing paradigms considered as potential key enablers. Although neither the premise nor the foundations of cloud computing are new (Gong, Liu, Zhang, Chen and Gong, 2010), cloud computing represents a set of emerging technologies, implementations and ecosystems that are still rapidly evolving. Cloud computing has built its foundations “on decades of research in virtualisation, distributed computing, utility computing, networking and more recently web and software services” (Vouk, 2008). Indeed, cloud computing represents a shift to computing as a service that is provisioned to users typically over the internet via large scale data centres or ‘clouds’. Recently it has been argued that “the real strength of cloud computing is that it is a catalyst for innovation and in keeping with Moore’s Law, as cloud computing becomes more cheaper and ubiquitous further opportunities for innovation will manifest” (Brynjolfsson, Hofmann and Jordan, 2010). Although cloud computing is growing in popularity at a phenomenal pace, with more and more businesses implementing various aspects of it to help deliver on strategic goals, academic research remains lagging behind rapid developments in the field, an issue first raised almost half a decade ago (for a discussion, see Sriram and Khajeh-Hosseini, 2010). Further research is warranted into the organisational value of cloud computing, to enable organisations make informed decisions about which cloud computing aspects and solutions may be most suitable to their needs, as vehicles for innovation and delivery on business goals. This paper contributes to that objective. To do so, we first identify those most significant cloud-centric issues facing organisations. We followed a systematic approach to the existing literature as per established guidelines (Bandara, Miskon and Fielt, 2011; Kitchenham, 2004; Levy and Ellis, 2006), spanning 2007 to present. Our keyword searches included initial early classifiers such as cloud computing, elastic computing, and utility computing; we also included the more categorical search terms Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS). Although the first public clouds were launched in 2005, we

note the appearance of peer-reviewed papers in 2007. For the review, and in particular to capture some of the discourse about cloud computing outside mainstream journals and before some journals explicitly included the topic in their interest areas, we included some conference proceedings, technical reports, market trend analyses and workshop papers.

It is now 2012. Since 2007, academic research on cloud computing has focused primarily on two aspects: technical issues associated with cloud computing, and implications for end users and enterprises using cloud computing. To date, there has been little discussion on business value (Iyer and Henderson, 2010; Iyer and Henderson, 2012). According to Google Trends (Google, 2012) the term cloud computing shot to prominence towards the latter of 2007, peaking in middle of 2011 (fig 1).

**Fig. 1. Google Trends result for the search term “cloud computing” (Google, 2012)**



In the next section we delineate cloud computing, delve into the various aspects and views of cloud computing, and focus on those of potential value to organisations seeking to innovate in modern economies.

### **In The Cloud**

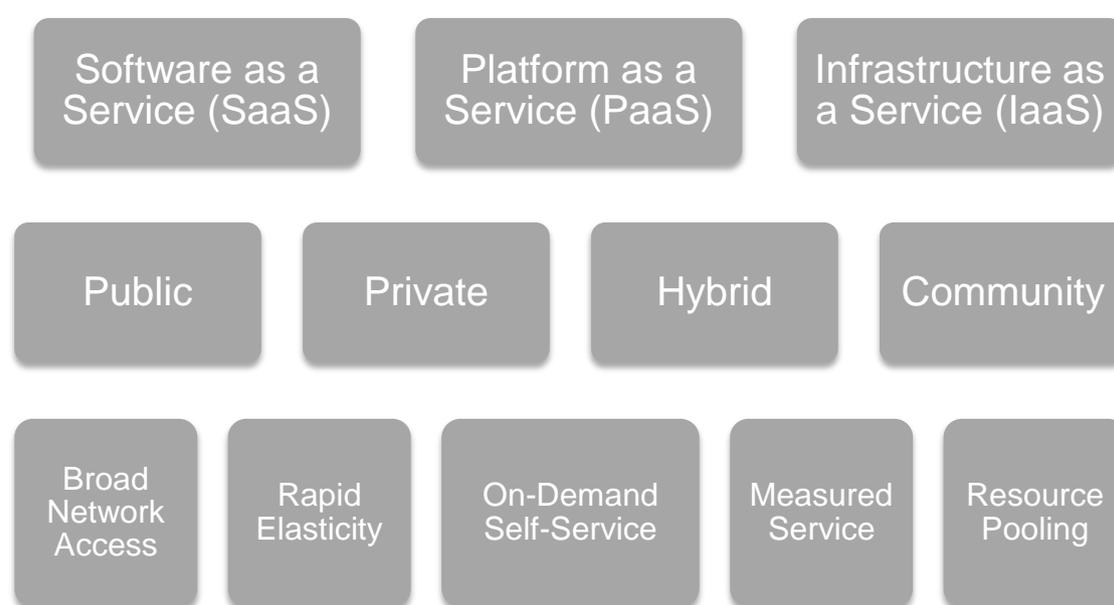
Between 2007 and 2010 alone there were 485 explicit cloud computing-related articles, which covered major topics such as technology, costs, personnel, security, quality and

compliance. Among 445 practitioner-oriented articles in the same period, relative percentage coverage and focus indicated 6 main issues: general topics (20.7%), technical topics (14.4%), company perspectives in cloud computing (12.1%), company perspectives in IT outsourcing (8.3%), and SaaS provider (7%)/ Microsoft Azure (7%). Concurrently, across mainly academic outlets (see Yang and Hsu, 2011), the coverage differed somewhat in relative emphasis, but covered essentially similar issues, with general & technical topics (40%), resource management (20%), grid vs. cloud computing (20%), SaaS/IT outsourcing (10%), and business management (10%). As such, at least across this period, it would seem that academic research has mirrored and recognised practitioner issues. However, further depth is required to determine if organisational concern and focus on issues in the cloud space are reflected adequately in research, and the most critical and topical issues within this broad categorical gamut remain to be identified. The first issue is to define and delineate cloud computing.

Concreting a clear complete and unified definition of cloud computing is necessary in order to help determine “areas of research and explore new application domain for the usage of clouds” (Vaquero, Rodero-Merino, Caceres and Lindner, 2009). In its entirety, cloud computing represents the evolution and convergence of several independent computing trends such as Internet delivery, ‘pay-as-you-go’ utility computing, elasticity, virtualisation, grid computing, distributed computing, storage, and more (Pallis, 2010). Its delineation varies in the academic literature: Vaquero et al. (2009) reviewed multiple definitions, with particular components emerging. These components are typified and converged in the description presented by Mell and Grance (2010) as that proposed by the American National Institute of Standards and Technology (NIST), describing cloud computing as “a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (for example, networks, servers, storage, applications and services) that

can be rapidly provisioned and released with minimal management effort or service provider interaction.” Further, this description is specific in detailing cloud computing as comprising five essential characteristics, four deployment models, and three service models. It is this definition and delineation of the evolving cloud computing paradigm that we employ in this paper, in particular what we term the 5-4-3 model, below.

**Fig. 2. The 5-4-3 model of cloud computing**



Looking upward in the model, the base layer has 5 components. These are essentially attributes that form the basic tenets of cloud-based computing. The first of these, broad network access, encompasses end user and device-based access to remote servers situating cloud services or applications, and describes access to computing resources over networks, whether intranets or public internet, using thick or thin client devices and multiple platforms including laptops, tablet PCs, smart phones, and new emerging computing devices. Essentially, this component assumes that end users can connect to remote servers. The

second, rapid elasticity, describes a cloud service provider managing a user's resource utilisation based on evolving needs, with a cloud service deterministically scaling up or down to meet user needs. The third, on-demand self-service, describes a requirement from end users for ubiquitous computing capabilities such as storage or processing power at any time, without the requirement for human interaction with the service provider. The fourth, measured service, represents the provision of user-based resource consumption metering by cloud service providers. Lastly, resource pooling, represents the provision, using multi-tenant models, of pooled computing resources to multiple consumers, where physical and/or virtual computing resources are a shared resource, in essentially a one-to-many provisioning relationship.

Many aspects underpin these 5 components (See Buyya, Yeo, Venugopal, Broberg and Brandic, 2009; Gong et al., 2010; Vaquero et al., 2009; Vouk, 2008). Amongst these are user-friendly user interfaces to cloud services and applications, particular technologies and approaches to service provision such as system virtualisation, leverage of existing best standards in distributed computing, network optimisation, resource sharing techniques, and security. As enablers of innovation, some of these components are provision-dependent, that is, the cloud service provider must provide the functionality, for example, deterministic and automatic provision of elasticity and resource pooling. Other aspects such as network access can have dependencies on public policy in the organisation's jurisdiction, for example, governmental provision of adequate growth-capable broadband. As such, it becomes incumbent on organisations to assess these dependencies, as deficiencies in any of these 5 components can negatively impact the potential for innovation. As the base layer of the 5-4-3 model, all 5 components being in place and of high quality provide only a common denominator, none will provide innovative capacity in itself, and together provide an

innovation platform depending upon how each component is leveraged, but their absence or suboptimal provision can impede innovation.

The middle layer in fig 2 describes the types of cloud. When cloud computing services are offered in a ‘pay-as-you go’ manner to the public it is referred to as a public cloud. Examples include Microsoft Azure Services and Amazon Elastic Compute Cloud (EC2). The service is sometimes termed utility computing. The technologies underpinning public clouds reside on the premises of the cloud provider. A private cloud, typically provisioned for exclusive use by a single organisation, describes the “internal datacenters of an organisation that are not made available to the general public” (Armbrust, Fox, Griffith, Joseph, Katz, Konwinski, Lee, Patterson, Rabkin, Stoica and Zaharia, 2010). Unknown parties do not share resources. The cloud may be managed by the organisation or by a third party. Amazon’s Elastic Compute Cloud (EC2) also offers private cloud services. A community cloud extends a private cloud, provisioned for specific use by a community of organisations or users for shared purposes, for example, security or legal compliance (Iyer and Henderson, 2010). A hybrid cloud comprises some combination or variant of the previous models. The innovative value of these various types of cloud lies in a trade-off between costs and overall control. Private clouds can be relatively highly secure and offer the most complete degree of internal control in terms of user access, authentication, data governance and so on, but tend to be pricey to set up. Hybrid or public clouds are generally less costly, with openness trading against investment. The innovation value to organisations rests with the cloud structure that best facilitates the organisation to focus on innovating its core competencies while balancing this focus with the cost of cloud-based services.

The top layer in fig 2 describes cloud computing’s well-established service models, differentiated into three distinct categories depending on the capability provided, and referred

to as the SPI (Software, Platform, Infrastructure) model (Gong et al., 2010; Mell and Grance, 2010; Vaquero et al., 2009). The first of these three, Software as a Service (SaaS), describes a computing scenario where the cloud provider allocates the user with software resources and capabilities, delivered through the user's web browser or thin client download, eliminating the need for the user to install or manage complex software or acquire additional hardware. The resources run on the cloud infrastructure. SaaS may be used to reduce the operating costs of a business, and aims at replacing applications on a PC (Gong et al., 2010). SaaS benefits to both service providers and end users are well-documented (see Armbrust et al., 2010). Organisational-level SaaS examples include customer relationship management (CRM) as a service and cloud enterprise resource management (ERP). Productivity applications include email, instant messaging, virtual desktops, and office automation such as Google Docs (Lenk, Klems, Nimis, Tai and Sandholm, 2009); with consumer- or citizen-based applications including wikis, blogs, social networking and web hosting (Rabai, Jouini, Aissa and Mili, 2012, in press). The second component in this layer describes service provisioning of computing platforms, Platform as a Service (PaaS). Here the cloud provider allocates the end user with a complete computing environment, typically for software development or application testing through provision of developer tools, database management, or testing functionality (Rabai et al., 2012, in press). The end user may deploy created or acquired applications onto the cloud. An examples of PaaS is Google's Application Engine. The third and last component in this service layer is Infrastructure as a Service (IaaS), where the cloud provider allocates storage and computing resources to an end user, through the provision of (multi-)server storage or processing, or virtualisation of computing infrastructures. It represents the outsourcing of a complete computing infrastructure. Resources are only allocated to a single tenant or client. An end user "has control over operating systems, storage, and deployed applications and [may have] limited control of select networking

components ..... the end user does not control the underlying infrastructure” (Mell and Grance, 2010). Examples of IaaS include Amazon’s Elastic Compute Cloud (EC2) and GoGrid’s ServePath. Accessing and integrating these services necessitates various interaction tools at both the user- and software levels; Rabai et al. (2012, in press) have broadly grouped these into three categories supporting application integration, reporting and analytics, and user portals. Such tools serve to facilitate “seamless interaction with all the underlying Every-thing-as-A-Service layers (XaaS or EaaS)” (Pallis, 2010). Further, Lenk et al. (2009) have proposed a fourth element to this layer, Humans-as-a-Service (HaaS), citing examples such as Amazon’s Mechanical Turk crowdsourcing service, and human-centric information aggregation services such as Iowa Electronic Markets. However, it may be argued that such human-intensive services are a consequence of the SPI elements rather than an additional element, or it may be the case that human-centred service-based activities are a natural evolutionary component. Nevertheless, the SPI model parsimoniously captures the various categorical delineations of service-based cloud activities, providing an overall descriptor for disparate descriptions of service architectures, from the 5-layer ontological stack proposed by Youseff, Butrico and Da Silva (2008) to the definitional components proposed by others over the last half decade (Buyya et al., 2009; Gong et al., 2010; Iyer and Henderson, 2010; Sultan and van de Bunt-Kokhuis, 2012; Vaquero et al., 2009; Yang and Hsu, 2011).

The innovation value of this layer in the 5-4-3 model is dependent on organisational choices made regarding the immediate sub-layer. Choices in this mid-layer can determine the organisational interest in the top service layer. Essentially, innovation can be facilitated by channeling various outbound organisational services through one of the SPI components, and is dependent on the business focus of the organisation. For example, provision to customers of virtualised computing environments may be very useful to software development companies

delivering new software for customer testing, and provision of this through cloud-based SaaS may provide a more effective or improved customer relationship, which in itself may facilitate further business with that client, or increased customer satisfaction. Such benefits have been shown to be instrumental in studies on IS success and acceptance.

### **Conclusion**

This paper described cloud computing using common classifiers that have become prevalent over the last half decade, and presented these in terms of what we have called the 5-4-3 model. Taking the model layer by layer, the paper described innovation potential across components. However, further research is necessary into the particular innovation value of discrete components of the model, to facilitate the construction of an innovation pathway (or pathways) through the model, through which organisational management may traverse or perhaps wade to facilitate a more focused concentration on core competencies and as a vehicle for innovation. Although the identification of cloud-related business value has recently been explicated (Iyer and Henderson, 2012), further research is warranted into cloud computing to enable organisations make informed decisions about which aspects, implementations and solutions may be most suitable to their needs, as vehicles for delivery on business goals, and facilitators of competitive advantage.

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