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Research article

A critical review of cloud computing: researching desires and realities

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Abstract

Cloud computing has become central to current discussions about corporate information technology. To assess the impact that cloud may have on enterprises, it is important to evaluate the claims made in the existing literature and critically review these claims against empirical evidence from the field. To this end, this paper provides a framework within which to locate existing and future research on cloud computing. This framework is structured around a series of technological and service 'desires', that is, characteristics of cloud that are important for cloud users. The existing literature on cloud computing is located within this framework and is supplemented with empirical evidence from interviews with cloud providers and cloud users that were undertaken between 2010 and 2012. The paper identifies a range of research questions that arise from the analysis.
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Introduction

Cloud computing has emerged as a potentially disruptive convergence of developments in computing power, data transmission speeds and the use of internet and mobile communications (Castells, 2001). At its most basic, it is a form of outsourced shared-resource computing (Babcock, 2010; Durkee, 2010) in which computing is pooled in large external data-centres and accessed by a range of customers through the internet.

Since its emergence around 2007 (Baker, 2007; Lohr, 2007) the topic has exploded in interest within academic and technical literatures ranging from the presentation of technological details associated with the provision of cloud services through to opinion pieces about the potentially revolutionary impact of cloud computing as 'a new paradigm' of computing (Carr, 2008; Zhang *et al*., 2010). It is difficult to fully make sense of this diverse set of publications.

This paper contributes to the understanding of cloud computing by providing a review of cloud computing theory and practice. The paper empirically grounds this review by evaluating the claims and trends identified in the literature through comparison with the experiences of cloud vendors and users identified in over 30 interviews undertaken between 2010 and 2012.

This enhances the existing reviews of cloud found within the information systems literature (e.g. Iyer and Henderson, 2010; Saya *et al*., 2010; Behrend *et al*., 2011; Janssen and Joha, 2011). The paper further identifies research questions within this framework for information systems scholars.

In this paper, cloud computing is understood in terms of the evolution of two distinct strands that come together to provide cloud computing. The first strand emerges from technological innovations such as virtualisation, high performance networks and data-centre automation (Boss *et al*., 2007; Armbrust *et al*., 2010). The second strand emerges from a more distinct emphasis on service-based perspectives (Vouk, 2008; Etro, 2009), which shifts attention from the management of technology assets to consideration of customer value from the use of technology services (Grönroos, 2011).

The review is structured around a framework of 'desires' for cloud computing: characteristics of cloud that are desired by cloud users (Table 1); see also Willcocks *et al*. (2011b). In keeping with the two strands above, cloud is seen to encompass technological desires and service desires.

The next section provides background and a working definition of cloud computing. This is followed by an

Table 1 An outline of the cloud desires framework

The technological dimension of cloud desire	
Equivalence	The desire to receive a technical service which is at least equivalent (in terms of security, latency and availability) to that experienced when using a locally running traditional IT systems.
Variety	The desire to receive a service which provides variety corresponding with the use for which the service will be put.
Abstraction	The desire to receive technical services which abstract away unnecessary complexity for the service they provide.
Scalability	The desire to receive a service which is scalable to meet demand.
The service dimension of cloud desire	
Efficiency	The desire to receive a service that helps users be more efficient economically.
Creativity	The desire to receive a service which aids innovation and creativity.
Simplicity	The desire to receive a service which is simple to understand and use.

overview of the framework of desires and the empirical evidence used in the paper. The paper then presents the technological and the service dimensions of cloud computing desires. The paper ends by discussing the consequences of the analysis presented including a review of a series of further areas for research.

Understanding cloud computing

The importance of cloud computing

Hyperbole surrounds many IT innovations but cloud computing in particular is being taken seriously by the IT industry and by IT purchasers. Steve Ballmer (CEO of Microsoft) suggests cloud represents a $3.3 trillion 'transformation that's going on in the computing world' (Ballmer, 2010b) and that Microsoft are 'betting the company' on cloud (Ballmer, 2010a). A recent IBM survey suggested 90% of business and technology leaders expect to have implemented some cloud computing by 2015, with 40% expecting a substantial implementation (Berman *et al*., 2012). Another survey (Brousell, 2011) argues that most Chief Information Officers (CIOs) are evaluating cloud options as alternatives to traditional IT approaches. A 2010 survey conducted by Horses for Sources found that two-thirds of business and IT executives view cloud as an enabler for services delivery models that drive innovation in their organisations and key decision makers looking to devote 30% of their IT budgets to cloud services over a 5-year time-frame (HorsesForSources, 2010; Willcocks *et al*., 2011b).

Such growth is also reflected in the market for public cloud services, which Morgan Stanley suggests will face 50% compound annual growth (Holt *et al*., 2011). As early as 2010, Amazon's revenue from cloud was estimated at between $500 million and $700 million (*The Economist*, 2010). Forrester forecasted a global market for cloud computing of $61 billion for 2012 (Kirsker, 2012) and believe this will grow to $241 billion by 2020 (Dignan, 2011). Such benefits are not restricted to the private sector; UK government aims to save £1.4 billion over the next 4 years, in part by launching its own cloud service (Maude, 2011).

Currently the cloud computing marketplace is dominated by a few high profile companies (Brodkin, 2009). In the provision of raw computing and storage these include Amazon, Rackspace, 3Tera, EMC and AT&T, in providing software applications Google, Salesforce, Netsuite, Apple, SAP and Microsoft. Companies providing services for cloud providers include VMWare, Cisco, Akamai and Rightscale. Finally, there are large numbers of systems integrators and consultancies helping companies exploit cloud opportunities including Accenture, CA-technologies, Deloitte and IBM.

The technological origins of cloud computing

The idea of providing computing as a service through networks dates back to the 1960s (Kleinrock, 2005; Cafaro and Aloisio, 2011) when the provision of 'computing utilities' became a driving force behind the early development of the internet (Berman and Hey, 2004). Distributing IT infrastructure and connecting to it via a network emerged during the 1980s (Owens, 2009; Durkee, 2010), with 'Application Service Provision' (ASP). Examples of ASP include email services like Hotmail that emerged in the 1990s as a means to outsource applications as a service (Owens, 2009). Relatively short-lived perspectives like NetSourcing (Kern *et al*., 2002a; Kern *et al*., 2006) emphasised this process of outsourcing applications over the internet.

In practice, it was the 'dot-com boom' which began an explosion of interest in outsourcing applications as both networks and internet software matured. Early ASPs failed due to insufficient bandwidth and computing power (Kern *et al*., 2002b; Susarla *et al*., 2003); however, the dot-com boom resulted in a large increase in global fibre-optic networking dramatically reducing latency and costs (Hogendorn, 2011).

Improvement in networking was coupled with the emergence of a means of coordinating the 'on-demand' provision of large scale of computing resources, achieved by drawing on innovations around 'grid computing' (Foster and Kesselman, 2004b; Foster *et al*., 2008), 'utility computing' (Bunker and Thomson, 2006) and virtualisation on commodity hardware[1] (Killalea, 2008; Stanoevska-Slabeva and Wozniak, 2010).

At the same time, extremely large data-centres of commodity hardware began to be developed by companies such as Google, Amazon and Microsoft. This industrialisation of IT infrastructures and the transfer of computing activity from individual PCs and private data-centres to large external public data-centres accessible over the internet became known as cloud computing (Boss *et al*., 2007; Da Rold, 2009). This shift 'to the cloud' (Carr, 2008) is perhaps more accurately described as a move to computing being provided by large pools of automated scalable computing resources (Cafaro and Aloisio, 2011) and associated applications (Cusumano, 2010).

Definitions of cloud computing

The move to scalable data-centres allowed computing resources to be purchased (or, perhaps more accurately rented) on-demand and in a scalable manner via the internet. Around 2007 the term cloud computing began to be used to reflect the use of the internet (usually represented figuratively as a 'cloud' in diagrams) to connect to such services (Regalado, 2011).

This focus on the internet and scalable external data-centres is reflected in the most widely adopted technical definition of cloud computing from the US National Institute for Standards and Technology (NIST): 'Cloud computing 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' (Mell and Grance, 2011).

This definition focuses on the cloud as a platform for running applications and while this is an important element, it downplays the role of applications that run on these platforms. Alternative definitions, such as those provided by Boss *et al*. (2007), emphasise both platforms and the types of application that run on them. For them the platform 'dynamically provisions, configures, reconfigures and de-provisions servers as needed', allowing applications to scale through their hosting in large data-centres. Applications are 'extended' to be accessible through the internet, thus using the large data-centres and powerful servers to host them. Under Boss *et al*.'s (2007) definition anyone can access such applications via an internet connection – highlighting the significance of the access device such as PCs and laptops (Cubitt *et al*., 2011), tablets, smartphones and other forms of mobile computing (Iyer and Henderson, 2010). Recent innovations include the use of cloud computing by smart devices that include internet-enabled sensors for example coffee makers that report errors to the cloud (Pritchard, 2012).

Cloud for cost reduction and green IT

It has been estimated that around 53% of the cost of a data-centre relates to electricity and cooling (Zhang *et al*., 2010). Exploiting recent improvements in network connectivity has enabled cloud companies to locate their large data-centres in locations where power and cooling are cheaper and potentially more environmentally friendly. Owing to their large size such data-centres can also benefit from economies of scale in electricity, bandwidth, operations and staff and software and hardware leading to reductions in the costs of these resources by a factor of 5 to 7 (Armbrust *et al*., 2010). However for large companies, who have already undertaken extensive consolidation of their existing infrastructures, the cost savings associated with moving to the cloud may be significantly lower (Forrest, 2009).

These cost benefits, and decisions to use environmental power sources, have been argued to allow cloud to improve the 'green credentials' (Cubitt *et al*., 2011; McKendrick, 2011) of users by reducing the environmental impact of their IT. However, a recent Greenpeace report criticises cloud computing for hiding energy consumption costs within service charges and thus actually making it harder for companies to evaluate their environmental impact effectively (Greenpeace, 2010). For example, an Apple iCloud data-centre is estimated to require the equivalent power to 80,000 US homes (West and Goldenberg, 2012), yet its users are unable to identify their personal contribution to this power usage. Further cloud computing has allowed the innovation of many new consumer services that rely on power usage in the data-centre (such as Google's Voice-Search or Apple's Siri) that users are often unaware of.

Beyond the fixed cost savings detailed above that arise from data-centre consolidation and location (Creeger, 2009), the literature also indicates particular types of computing demand which can gain specific cost savings. These include when demand for IT services varies considerably over time, when demand is unknown and when short-term rental of extensive computing facilities offers cost savings over long-term utilisation of a small number of servers (Armbrust *et al*., 2010). As Gray (2008) analyses in detail, cloud costs are based on the characteristics of use in relation to networking, computation, data-access, data-storage.

In summary, there are some specific reasons why cloud computing can offer cost savings and yet (as we will discuss below), for enterprises, the decision on cloud is more complex than purely cost advantage.

Enterprise benefits of cloud computing

Enterprises typically follow developments in the technology marketplace to determine how well aligned these developments are with their own evolving business strategies. The business-led adoption of cloud computing shapes a further key area of the literature on cloud computing in which the most pervasive business benefits attributed to cloud relate to the perceived opportunity to drastically reduce costs and complexity for enterprises (Baker, 2007; *The Economist*, 2009) and to offer new, and as yet unknown, innovation opportunities (McAfee, 2011).

Carr's (2003) pronouncement that 'IT doesn't matter' and that cloud might lead to the demise of the IT department is influential in this regard. Carr later argued that the IT department 'will have little left to do once the bulk of business computing shifts out of private date-centres and into "the cloud" and as employees control their IT directly' (Carr, 2008). Such arguments reflect the post dot-com zeitgeist of IT cost-reduction; a time when capital expenditure on IT accounted for nearly half of an organisation's capital costs (Stewart, 2003) and CEOs lacked a 'visceral understanding' of such costs (Ballmer, 2010b).

For large enterprises and governments this position suggests that much of the appeal of cloud lies in gaining a better control over, and reducing, the cost of data-centres. In particular, cloud allows the reclassification of IT from an expensive 'capital expenditure' (requiring finance which may be difficult to raise) to a pay-as-you-go 'operating expenditure' (Nikolov, 2011).

Other business benefits of cloud can include a reduced demand for skilled labour where skills shortages exist (e.g. South East Asia) (Luftman and Zadeh, 2011). For universities and education establishments it allows the provision of computing laboratories to students and bulk processing services for research, on an isolated and pay-per-use basis (Vouk, 2008; Sultan, 2010; Sarkar and Young, 2011). For SMEs it offers a compelling opportunity through lower barriers of entry to computing (World Economic Forum, 2010) allowing access to large data-centres to provide unique services for niche markets previously inaccessible due to high capital costs (Weinhardt *et al*., 2009).

This has the potential to create new markets (Etro, 2009) particularly in areas like business intelligence which previously required significant IT investment (Mircea *et al*., 2011). For emerging countries cloud computing offers yet another opportunity to 'leapfrog' to advanced technology by connecting to cloud providers outside their countries (Goundar, 2010; Kshetri, 2010; World Economic Forum, 2010).

Cost-savings and the desire to focus on core capabilities are also the most frequent motivations for traditional outsourcing (Lacity *et al*., 2009) yet there is growing recognition that there are risks associated with focussing solely on questions of cost. In particular, it is increasingly understood that achieving business innovation through outsourcing is incompatible with an adversarial procurement strategy where the profit motive is not shared between parties. Instead a step-change in the kinds of relationships between clients and outsourcing providers (Whitley and Willcocks, 2011) is required. Thus while the technological aspects of cloud computing and shared data-centres might support the cost-cutting agenda, the appeal of cloud seems to be wider than this restricted and restrictive focus

In summary, cloud computing represents a number of technical innovations which have enabled services which appeal to businesses' desires. Innovation in data-centres also provides opportunity for innovative business opportunities through cloud computing (a theme we explore in detail below). However in contrast to commoditised outsourcing offerings in which cost becomes a key differentiator and driver, our research below suggests cloud services may offer innovation opportunities as well as cost-saving. The IT industry has however also engaged in significant marketing efforts promoting cloud computing, with many companies rebranding existing offerings as cloud computing (so-called 'cloud-washing' (Babcock, 2011)). It is thus important to develop tools which enable the evaluation of cloud computing beyond such marketing efforts. The next section describes this paper's desires framework.

Cloud computing desires: evidence from literature and practice

When confronted by any potential innovation in computing, organisational decision makers are faced with a complex sense-making problem (Swanson and Ramiller, 2004). How are they to comprehend the nature of the innovation and make meaningful decisions about adoption? This is particularly problematic during the early stages of an innovation's diffusion, when community know-how is limited (Wang and Ramiller, 2009) and the technology is defined more in terms of its expectations than its implementation (Brown and Michael, 2003; Swanson, 2003; Borup *et al*., 2006).

Further complication arises from the experience of numerous fads and fashions relating to technology, where each and every technological innovation appears to promise to solve all organisational needs often on the basis of limited or non-existent empirical evidence (Baskerville and Myers, 2009; Hirschheim *et al*., 2012).

In this scenario an analytic device that helps structure the available evidence can prove invaluable for those seeking to develop their know-how about the particular innovation. A range of such structures have been proposed in relation to the information systems literature on cloud computing. For example, Iyer and Henderson (2010) present cloud computing in terms of seven 'capabilities' (listed as controlled interfaces, location independence, sourcing independence, ubiquitous access, virtual business environments, addressability and traceability, and rapid elasticity), whereas Janssen and Joha (2011) talk of 'challenges for adoption' (listed as organisation, performance, decision, contract and relationship).

We structure our understanding of cloud in terms of a series of 'desires'. That is, we take the perspective of cloud adopters who 'desire' various things from cloud computing and cloud providers. To desire is 'to have strong wish for; to long for, covet, crave' (OED) and brings with it connotations of lust and emotional (rather than rational) response (Laan and Both, 2008). This concept of 'desire' allowed consideration of the realities of cloud as unsatisfied, and the possibilities that these unsatisfied desires might actually strengthen their desirability. Considering desires provides a critical edge to a review of literature, including professional literature that is, for the most part, uncritical (or excessively cynical) and hyped. The notion of unsatisfied, unachievable desire reflects existing views of IT as aspired-to despite being discussed in the literature as available and present (a problem Friedman and Cornford described as the 'problem of tenses' (Friedman and Cornford, 1989)).

These desires include both business-led and technological considerations. Moreover, as desires can either be satisfied or remain unfulfilled, it is possible to locate evidence from cloud developers and providers within the same desires framework, thus covering both 'outward looking and inward looking perspectives' (Birman *et al*., 2008) and allowing exploration of the realities of cloud computing today.

To develop, elaborate and operationalise our desires framework, we drew on the available literature on cloud computing. This literature includes academic studies on cloud computing, as well as the professional literature such as industry white papers and technical reports. This review of the literature was combined with detailed empirical evidence obtained from a series of over 50 in-depth interviews with a range of cloud providers and users, over 30 of which were transcribed for analysis purposes. These interviews were undertaken between 2010 and 2012 and further details of how the interviews were undertaken,

Table 2 Details of interviewees from whom quotes are used

Interviewee code	*Job title*	*Organisation*
i1	Head of Infrastructure Solution Management	Large enterprise software developer and SaaS applications provider
i2	VP Marketing	SaaS company providing enterprise applications and PaaS
i3	Senior Director of Platforms Director of Product Marketing	
i4	Chief Technology Officer Systems Operations Director	Multichannel marketing company
i5	Group Strategy Director Client Engagement Strategist Technology Strategist	 Cloud Software company providing cloud providers and enterprises with software to run data–centres.
i6	Consultant	
i7	Consultant	
i8	CEO	Cloud based SaaS service provider
i10	CEO	Health Cloud Provider
i11	Managing Director Cloud Product Manager	Multi–channel global media company Cloud provider
i12	Deputy Director of a Government Cloud project Security Manager	European Government IT procurement strategy department. Transport Company using Cloud
i13	Innovations Team	Global Software Development Company and SaaS and PaaS provider
i14	Managing Director of Cloud Computing Partner	Global Systems Integrator
i15	Senior Manager, Outsourcing Marketing CIO Senior Consultant/ Change Manager	 Data–centre and IT infrastructure consultancy
i16	Service Director (ITSM)	
i17	Head of Data-centre Solutions	
i18	Senior Consultant	
i19	CIO to Internal Delivery	Cloud Computing SaaS, PaaS and IaaS provider and consultancy
	Global Marketing CEO CIO Head of Research and Development	 Provider of Cloud Software for Enterprises Technology SME

how participants were selected and how the resulting information was analysed in order to develop the framework is provided in the Appendix to the paper. When structured in terms of desires, this combination of literature and practitioner experiences makes it possible to identify desires and aspects of desires where the need for further research is particularly strong.

Table 2 details the job title and organisation of those interviewed for this research. A subset of these transcribed interviews have been quoted[2] from within the analysis and these have been given participant codes (of the form [ix]) to aid cross-referencing. The additional transcribed interviews informed the analysis but are not used for quotations.

Technological dimension of cloud desires

This section reviews the technological dimension of cloud computing desires by exploring the IT industry-led technical innovations upon which cloud computing is founded. Four key technological cloud desires were identified from our interpretation of the literature and our analysis of the empirical evidence. These are 'equivalence', variety',

Table 3 Technological dimension of cloud desires

Security **Equivalence**	The desire to receive a technical service which is at least equivalent in *security* to that experienced when using a locally running server.
Availability **Equivalence**	The desire to receive a technical service which is at least equivalent in *availability* to that experienced when using a locally running server.
Latency **Equivalence**	The desire to receive a technical service which is at least equivalent in *latency* to that experienced when using a locally running server.
Variety	The desire to receive services which provide a level of complexity (variety) commensurate with the operating environment.
Abstraction	The desire that non-pertinent complexity be hidden, in particular that the complexity of managing the underlying IT infrastructure and software be abstracted and hidden.
Scalability	The desire to receive a service which is *scalable* to meet demand.

'abstraction' and 'scalability' and are described in more detail in Table 3. We subdivide equivalence in terms of security, availability and latency.

Considering the desire for cloud computing through a technology dimension highlights the decisions made in relation to existing computing provision. For many organisations contemplating cloud computing the decision is not in isolation of their existing computing resources, but in comparison to such resources. A key focus of this section is thus upon the ways in which cloud computing compares with existing organisational IT. At the end of this section a number of potential avenues for further research are outlined.

Equivalence

Cloud computing is often intended to replace existing, locally hosted technology infrastructure. As a result, the first technological desire is the desire for equivalence. This is the desire that the cloud provider must endeavour to guarantee security, availability and response time which are at least equivalent in quality to that experienced by a locally running client-server service on a local area network (Buyya *et al.*, 2009a; Brynjolfsson *et al.*, 2010). The provision of such equivalence is central to the technological realities of cloud computing and this can be understood in terms of three aspects: security, availability and latency. If this desire remains unfulfilled cloud adoption is unlikely to proceed.

Security equivalence

A significant challenge in providing the desired technological equivalence concerns security and this topic dominates much of the existing cloud computing literature.

There is a perception of insecurity in housing data within the cloud (Benlian and Hess, 2011). As interviewees expressed this 'there's a great confidence and comfort that you get if you walk around your server racks, as you hug the hardware' [i2], 'there's a sense that you can actually physically go there and deal with [problems]' [i5].

In practice, it is a detailed technical question as to whether a cloud data-centre wholly connected to the internet is inherently less secure than a data-centre on a private network when access to the network itself is possible via the internet (Krutz and Vines, 2010; McAfee, 2011). Indeed as networks themselves become virtualised such questions become increasingly complex (Metz, 2012).

A key challenge for cloud computing security relates to the context in which the computing occurs. Cloud providers who operate globally distributed networks of data-centres may face specific security risks (for example in terms of terrorism or cyber-attack) and may also present unique legal issues (Nelson, 2009; Denny, 2010) regarding liability for security infringement. For example, large, shared services may increase the risk of having data accidentally searched or seized by the authorities who may be seeking another user's data (Couillard, 2009).

Similarly certain user-contexts have specific security demands (e.g. Government (Paquette *et al.*, 2010) or financial services). Government security requirements may result in enhanced levels of security assurance in the marketplace from cloud providers who wish to be eligible for government contracts. This supports Nelson's (2009) belief that governments can encourage new cloud services. Indeed, outsourced hosting services are already employed in many industries for highly sensitive data, including many general practitioners in the UK who host health records in a secure cloud.

Owens (2009) suggests that the large scale of many cloud providers presents particular problems for security, both technologically and organisationally. The security challenges associated with any offsite hosting of data and services (i.e. outsourcing or cloud) include determining who can access customer data, denial of service attack prevention, perimeter security policy, resource starvation, data backup and compliance (Owens, 2009). In addition, there is a need to trust systems administrators whether in the cloud (Ryan, 2010) or within the private data-centre.

The co-hosting of many companies' data in a cloud data-centre can introduce distinctive risks. 'People hack brands' [i4] and the risk of another brand 'sharing' a cloud provider cannot be easily calculated. For example, one unintended consequence of Amazon and DynDNS hosting WikiLeaks was that these services were targeted by hackers with consequent effects on other users of their services.

Although cloud services may change the security risk profile (Anthes, 2010), it was also suggested in interviews that the cloud providers may be better able to manage security, respond to distributed attacks and invest in sophisticated security hardware and software; facilities that are unavailable to all but the largest enterprises. Indeed cloud providers may be able to spot unusual activity, which the individual companies would be unable to identify, by using security analytics to identify unusual behaviour patterns among pools of similar enterprises.

Moreover, given the relative novelty of cloud, providers are sensitive to the reputational dangers of security breaches: 'If the data-centre blows up, I'm going to be in the newspaper more often. I don't want to be in the newspaper more often, I need a [business continuity] solution and a [disaster recovery] solution … . I'm not saying I'm doing it to avoid the newspapers. I don't want my customers not to have access to their [records]' [i10].

Another interviewee argued that 'cloud is as secure as traditional really … . From a high level security point of view I'm not particularly concerned at all because [they will be using] the latest operating systems patch, all those sort of things. The basics are always going to be there' [i4].

Indeed Anthes (2010) highlights that cloud can simplify security issues for organisations by outsourcing them to companies with specialist security measures and skills. Durkee (2010), however, is critical of this outsourcing of responsibility, suggesting it creates the risk of skills attrition – as companies who outsource to the cloud lose the skills to evaluate and manage their cloud providers. A number of guides now exist to provide support for auditing cloud computing risks (e.g. Krutz and Vines, 2010; Halpert, 2011).

In our view the challenge of security equivalence has less to do with the security issues *per se* than with the ability of companies to evaluate the benefits and risks of cloud-based systems (Knapp *et al.*, 2011). In undertaking such evaluation organisations need to look past the idea of 'security issues' and take more meaningful evaluations of risk.

Security equivalence therefore concerns the 'operational security of the business and the integrity of the party with which you choose to work' [i17] and evaluating operational security and risk is standard practice today. As Steve Ballmer usefully summarises 'as soon as you start pooling computing and data in new and interesting ways, really defining and really being careful about weighing up who owns what data and how it is controlled and used is a fundamental responsibility of every participant in that chain' (Ballmer, 2010b).

Significant emphasis is therefore placed on cloud providers demonstrating their security credentials transparently. For example, Amazon has moved to acquire existing security standards (e.g. ISO 27001) for its cloud service. One cloud provider interviewed agreed that transparency was important: 'we allow any of our customers to come in and do their own … testing for example. They can try to hack the system as part of their due diligence. They could come in and tour our data-centres and talk to our security experts' [i3].

Given the steps taken by cloud providers to increase the transparency of their security provisions, it is important to question the extent to which concerns about security equivalence are genuine, are based on an unrealistic assessment of current security risks or are simply a defence mechanism proffered by beleaguered IT departments who fear that their entire *raison d'être* will be lost to the cloud.

Availability equivalence

Although locally hosted infrastructures are themselves fallible with occasional downtimes for system upgrades and in response to component failure, successful cloud services must be able to match, if not exceed, the availability of local data-centres (Wailgum, 2009; Durkee, 2010) and their disaster prevention and recovery systems (Yoo, 2011). While a key benefit of cloud is dispensing with these redundant (and thus often unused) internal disaster prevention systems, users must be assured that availability is a key concern for their cloud provider.

As a result, cloud providers spend considerable effort in monitoring, managing and predicting the performance of their cloud services, particularly as outages receive considerable press attention (e.g. Hickey, 2011).

An important driver of availability equivalence is the extent of capacity planning and capacity management by cloud providers. In order to anticipate and plan for changes in demand, cloud providers and researchers are developing sophisticated business analytics techniques that are believed to provide better insights into likely demand peaks so that they can continue to operate within the service levels (including availability equivalence) offered to their customers (Espadas *et al.*, 2011). Metrics are increasingly generated, monitored and shared in real time with customers (e.g. http://trust.salesforce.com http://status.aws.amazon.com/) with some external parties producing similar metrics (e.g. http://www.awsdowntime.com/). Cloud providers believe that allowing customers to view availability statistics, incidence statistics and solution statistics 'builds trust' [i1]. Financial transparency can also be necessary for cloud companies, as the risk of cloud provider bankruptcy (and resulting unavailability) remains a significant concern among many users (Marston *et al.*, 2011).

An important lesson from studies of outsourcing relates to the notion of the 'winners curse' (Kern *et al.*, 2002c). Here, an outsourcing provider wins more outsourcing contracts than it was expecting. As a result, it finds itself unable to adequately support all its contracts fully with the unintended consequence that either all customers receive sub-standard service, or some customers (typically pre-existing ones) end up with poorer service than they had initially contracted for. Similar problems could arise if a cloud provider suddenly finds itself stretched to provide quality services (including availability) to all its customers.

Latency equivalence

A third aspect of equivalence that is desired for successful cloud implementation is latency. This means ensuring that the end user perceives no additional performance lags when they are interacting with a cloud based service. To a large extent, the investment in fibre-optic cabling has helped ensure this with Yoo (2011) demonstrating that for global companies who face internal network latency issues for offices that are a long distance from their central data-centre, the use of cloud computing providers with multiple data-centres may offer a significant performance improvements.

However while much cloud computing literature suggests that latency is no longer an issue, the interviewees were more cautious. One service provider noted that 'lots of people who work in networking say the cloud is fundamentally flawed because the network is the biggest constraint. You can put compute at the end of the network but if the network is limited, then no matter how powerful it is, you've still got that constraining factor' [i18]. Indeed companies such as Akamai.com and BT have specialised in responding to the challenges of latency for cloud companies and their users.

The extent to which this is a problem is relative to the application. For database usage where large records must be locked from other users during updates latency can be a significant problem, whereas small database lookups can be unproblematic – 'customers in Australia doing address lookups from our UK hosting providers … . In spite of the fact that some of the databases being queried are really significant … 20 million [records] … the actual query response time is really quick' [i8].

Another cloud user highlighted the importance of the cloud-providers internal network in issues of latency (confirming the statements made by Durkee (2010) and Hamilton (2008) and as suggested by Metz (2012)) noting 'I need to make sure that I'm dealing with providers that can provide the capacity and reduced latency that I need' [i7]. Similarly latency remains an issue for developing countries and this may jeopardise their desire to capitalise on the benefits of cloud (Goundar, 2010; Kshetri, 2010).

Hybrid clouds as a response to the failure of equivalence

For companies who desire security, availability and latency equivalency but are unable to satisfy these desires with pure-play cloud offerings, there is growing evidence that a hybrid model, in which a service is divided into components according to the differing equivalence demands, is likely to be used. Here those components for which appropriate equivalence is achievable use the cloud, with other components, perhaps with higher security or latency demands, remain locally.

For example, while cloud services may be suitable for government services with low requirements for security assurance, systems with higher security levels may remain within local data-centres because cloud providers cannot guarantee security equivalence (additionally, such systems are more likely to provide bespoke functionality) (Sotomayor *et al*., 2009). Such hybrid models are also found in other domains as well, including media companies: 'whenever there was something that had huge security issues, or data needed to be stored somewhere we knew for various laws, [we] would … probably build a slightly hybrid system, that maybe had a box that we were in control of, to store core data and everything else was in the cloud' [i11].

This hybrid model was also employed by a cloud provider of health records that hosted 25 million patient records. Because of intermittent networks (i.e. problems with latency equivalence) and the need to update records centrally without problems the company relied on local cloud-access devices (PCs, iPads etc.) which ran local software 'apps' to ensure the medical records were still available even if the network failed or became slow and to ensure that updates to records ran fully and safely. In the CEO's words 'pure cloud is too dangerous in clinical terms' [i10].

One provider suggested that the only viable option for enterprise class systems where legacy systems exist is to employ a hybrid model 'I think it's hybrids, it's absolutely 100% hybrids at the moment. Nobody's doing a 100% pure cloud play as we speak to my knowledge' [i17].

Variety

Variety, as used here, is a measure of complexity (Ashby, 1956) and relates to the number of possible states in a situation (Espejo, 2000). The term is used to denote the desire that the cloud service must provide requisite variety (Ashby, 1956), that is variety greater than or equal to the variety required by the user of the cloud service to face the complexity of their business environment. The variety of information systems has long been discussed (Swanson, 1979; Schwaninger, 1997; Espejo, 2000). Put simply a cloud service must provide sufficient variety (in terms of its functionality or its ability to be programmed and altered for users) in order to meet the needs that users intend to use it for. Thus the variety of a service is related to the 'number of distinguishable states that it could take on' in use (Pickering, 2010).

The most widely adopted categorisation of cloud computing services focuses on the provision of computing itself 'as a service' (aaS), considering differences between Software (SaaS), Platform (PaaS) and Infrastructure (IaaS) (e.g. Armbrust *et al*., 2010; Zhang *et al*., 2010; Marston *et al*., 2011; Yoo, 2011). While these distinctions are intuitively appealing, they are logically problematic. IaaS, PaaS and SaaS all involve internet-based access to software: the virtualisation software that provides simulated computing instances for IaaS, a platform operating system for PaaS and an application for SaaS. As they all provide software systems the only significant differences between them relates to the extent to which they are general-purpose (i.e. their variety) – and thus the capacity of the user to adapt the service in order to match the variety required for their business environment. This paper therefore doesn't follow the traditional use of SaaS, Paas and IaaS and instead focuses on the underlying variety of cloud computing services.

Variety for cloud services is therefore more helpfully understood as a spectrum from the most specific transactional cloud service with extremely limited variety (e.g. Bit.ly which takes a URL string and returns a much shorter URL string – it is very simple and has no opportunity tailoring or programming the service and thus exhibits low variety) through to cloud computing services with exhibit extremely large variety approaching a Universal Turing Machine (Turing, 1946) with infinite storage and processing (Gleick, 2011) that happen to be accessible through the web. The huge numbers of computers deployed in the grid computing model (Foster *et al*., 2001), or Amazon's Elastic Computing Cloud (http://aws.amazon.com/ec2) are examples of cloud services with extremely large variety. Such services can be adapted in a multiplicity of ways to respond to the complexity of users' business environment.

This spectrum thus encompasses SaaS (with various levels of variety depending on the functionality and tailorability) through PaaS (an arbitrary point on the spectrum dependent on the level of variety offered by the PaaS platform) towards IaaS (with large-scale virtual computing instances and thus very large variety).

One consequence is that users must attempt to contract for services without necessarily knowing the variety they will need in the future. As one interview highlighted this is a difficult challenge 'Every single vendor in the world will tell you … their product is more … flexible than everyone else's … . You can't possibly prove that in a [Request for proposals]' [i2] to provide a cloud service. We anticipate that further research is required to understand the management of variety. We also hope that using the concept of variety will improve the ability of companies to evaluate the decision to move to the cloud.

Abstraction

Abstraction is the process of hiding non-pertinent detail and only dealing with generalisations; in this case we use the term to relate to the desire to abstract away the complexities of managing and operating the underlying IT infrastructure and software of the IT service.

Cloud concerns computing services provided by layers of technology which are abstracted. For Weinhardt *et al*. (2009) such computing services are built on three layers – infrastructure, platforms and applications, with differing business models at each level. Iyer and Henderson (2010) add collaboration to this list – reflecting the collaborative nature of many such services. Youseff *et al*. (2008) define cloud in terms of abstraction as 'a new computing paradigm that allows users to temporary utilize computing infrastructure over the network, supplied as a service by the cloud-provider at possibly one or more levels of abstraction'. These authors see five layers of abstraction including hardware and operating system kernel, cloud software infrastructure (i.e., computational resources, storage and communications), then cloud software environment (also called the platform layer) and finally applications.

In order for users of cloud services to exploit variety to respond to the complexity of their problems, there is a necessary degree of unintended complexity created by the cloud service itself to which the users must themselves respond. Such complexity is created by the underlying computing infrastructure of the cloud service (the need to manage computers, power and cooling, storage, input–output, scale, backups, redundancy etc.) and how successfully such infrastructure is abstracted. There is thus an inverse relationship between variety (that is the complexity of a cloud services which users require to match their needs), and abstraction (the complexity of a cloud service which users usually wish to reduce and have abstracted).

The desire for abstraction is therefore also a spectrum from the least abstracted computing hardware (a physical machine hosted in a provider's data-centre and requiring the user to manage the whole application stack and the physical machine) to the most abstracted service. Our interviews suggested that abstraction from the underlying hardware was a significant desire due to the difficulty of managing the whole application stack in on-premises IT: 'the value proposition of going to the cloud is that they realise that they cannot do IT as well as a cloud vendor like [Our Company]' [i13].

Abstraction of computing is the key to cost reduction

One of the highest variety, and least abstract, cloud computing services is the provision of large numbers of computing instances (for example, Amazon EC2), using the technologies of virtualisation and workload management (Smith, 2005; Foster *et al*., 2008; Cafaro and Aloisio, 2011). Virtualisation is the most discussed form of abstraction within the cloud computing literature but has existed for decades on mainframes, providing multiple isolated duplicate simulations of a physical computer on one actual physical computer (Popek and Goldberg, 1974). In this way a single computer can host many simulated computers (virtual machines) using so-called hypervisor software. The emergence of cloud coincided with the availability of virtualisation on commodity hardware using hypervisor software from VMWare, Microsoft, Oracle, RedHat and Sun (Killalea, 2008).

Such abstraction of computing within cloud providers data-centres allows the use of cheap commodity hardware and enables the elasticity, load balancing and economies of scale which are fundamentally driving cloud computing's adoption and underpin its economic model (Armbrust *et al*., 2010). Crucially for cost reduction purposes, by automatically allocating these virtual machines to physical machines (and moving them among physical machines, or even archiving them to disk) it is possible to manage the demand for computing effectively across an entire data-centre or even the world (Wladawsky-Berget, 2004).

Such 'statistical multiplexing' (Armbrust *et al*., 2010) can, for example, allow a European holiday company's website (used extensively at the start of the year when people book their summer holidays) to reside alongside a consumer retail company (used heavily towards the end of the year) thus increasing utilisation rates for the shared hardware. Renting virtual machines from a cloud provider (rather than running a data-centre) removes the challenges of cooling, power, upgrades, failed disks etc.

Abstraction makes it harder to manage IT

There is also evidence, however, which suggests that abstraction within cloud computing makes it harder for companies to evaluate the quality of the underlying IT (a point also made by Durkee (2010)) and can lead to poor understanding of the nature of the service provided (and poor ability to evaluate its value). As one interviewee highlighted, the provision of a virtual machine through the cloud creates significant complexity for the user. 'Amazon … don't provide any managed service, it's all up to you. They provide the infrastructure, you've still got to manage the backup potentially and what goes on within Window and Linux and at that level' [i18]. Indeed Clarke (2012) concluded that many organisations fail to effectively risk-assess the use of cloud.

At the other end of our spectrum are highly abstracted services such as software applications like email. These services are very specific in their purpose and are thus standardised for large numbers of users. They are very useful as the problems faced by many organisations are (or can be) standard and exhibit low variety. 'When you look at the complete coding that you need in your company, maybe less than 10% is really strategic coding or coding for strategic function. 90% or even more is standard' [i1].

Scalability

Scalability describes the ability to quickly add or remove resources in varied granularity to allow the better matching of resources to workload. In this context, elasticity is a measure of the rapidity of such scalability. Traditionally these granular elements were servers which were slow and expensive to install or remove. By providing a platform which 'dynamically provisions, configures, reconfigures and de-provisions servers as needed' (Boss *et al*., 2007), cloud computing offers the ability to scale elastically. For some such elastic scalability is 'the true golden nugget of cloud computing and what makes the entire concept extraordinarily evolutionary, if not revolutionary' (Owens, 2009).

Most authors agree that scalability is central to cloud computing (Vaquero *et al*., 2008). Armbrust *et al*.'s (2009) influential paper goes further, arguing that scalability (and, by implication, large data-centres) is vital to cloud computing, although Zhang *et al*. (2010) challenge the assumption that scalability can only be provided by large data-centres. Earlier work in Grid computing (Boss *et al*., 2007; Foster *et al*., 2008; Cafaro and Aloisio, 2011) has proved influential in supporting the management of server workloads to enable scalability.

Among cloud computing proponents the narrative of elastic scalability has been highly influential. Many 'dot-com' failures were caused because the start-ups had limited web-server capacity and if their sites gained media attention these servers were quickly overwhelmed slowing the sites or making them unreachable (Benioff and Adler, 2009) and leading customers to drift away (as famously happened to Friendster.com to the benefit of Facebook).

More recently, the ability to scale computing elastically (Foster and Kesselman, 2004a, b; Foster *et al*., 2001) through the use of cloud servers has enabled dot-com start-ups like Animoto.com to match their growing demand (Creeger, 2009; Smith, 2009). Upon launch Animoto faced a doubling of its server loads every 12 h for nearly three days (Smith, 2009). Using an Amazon cloud infrastructure it grew from 50 to 3500 servers during this time (Armbrust *et al*., 2009).

Such elasticity allows cloud provider to align their offerings with customers' demands and provide the illusion of unlimited computing that can be purchased 'on-demand' on a pay-as-you-go basis quickly and easily. As one interviewee stated 'if you request provisioning on a server, you should get that within a matter of hours. And you should also be able to turn off the use of the server or storage within … a matter of hours. And that should be reflected at least within monthly billing' [i16].

Despite the professional and academic literature being vocal in support of scalability, many interviewees were more circumspect. The time to provision additional resources may be a key differentiator among cloud providers; however one specialist interviewee suggested the industry was reluctant to support self-service provisioning on-demand for enterprises: 'In my experience both from the service provider side and the Enterprise customer side, I think they have to go through a cultural shift and a mind-set shift to accept allowing their end-users to do on-demand self-service provisioning. What I'm seeing is that, on a service provider side, they're still wanting to … work within the context of their managed services. Likewise on the Enterprise customer side, I've seen resistance from IT at the management level of … the concept of allowing their end-users within the Enterprise to do self-service on-demand provision' [i6].

Scalability and the impact of variability in demand

Within certain industries spikes in demand are standard, retail being an obvious example, and this makes scalable cloud-based resources an attractive option. For example, within the television industry demand 'was very spiky, if something was promoted on the telly, then people would, for the next three minutes, go on-line and then never again … we were forever having servers going down, it was too expensive to manage that peak … we spotted the capability of managing spikes very easily through cloud computing' [i11]. Contemporary computer science research has also highlighted the challenges of modelling peak demand and demonstrated the complexity of efficiently managing the scaling of cloud resources (Espadas *et al*., 2011).

Even within business without such spikes the management of scale is difficult and it is usual to over-provision IT hardware – 'Typically … they look at a project [and] implement enough IT infrastructure to support that project for up to three years. And typically you might find that only 50% of that capacity is used up until the third year of the project … It's spent two years sitting around doing nothing. [An elastic cloud] model means that people could … literally turn on the tap faster when they need more power, turn it down when they less and pay directly for that' [i16].

In this way scalability can lead to a decline in the average amount of computing commissioned by giving users confidence that they do not need to over-provision, or hold onto unused resources, as they can acquire them when needed in minutes. The net effect of these patterns of behaviour is to reduce headline demand for cloud services, although cloud providers need to be able to respond to the demand levels hidden behind these behaviours.

Elasticity is not without its problems (Saya *et al*., 2010) as certain applications cannot be scaled elastically (relational databases in particular) (Brynjolfsson *et al*., 2010). Cost calculations for elastic demand are complex (Vouk, 2008) and can be unpredictable. Moreover, as cloud computing expands it is likely to face the challenges of scaling cloud data-centres (Abbot, 2009; Weinhardt *et al*., 2009). Indeed an IBM paper suggests that as applications and users of cloud computing grow in number scalability problems are likely to increase (Rochwerger *et al*., 2009).

The challenge of managing scale for cloud providers

Given the previous discussion about abstraction and variety, it is reasonable to expect that cloud providers offering abstracted computing instances (at the level of IaaS or PaaS) will find fewer challenges managing scalability than companies offering highly abstracted applications (e.g. SaaS). In addition, experience of managing these processes will inevitably prove significant, giving companies

Table 4 Research questions from the technological dimension of cloud desire

Equivalence	• In what ways does the risk profile of cloud-based services differ from traditional systems and how might risk from cloud services be evaluated? • What are the factors affecting risk perception as they apply to cloud computing? • What is the efficacy of signalling security measures, such as certification and offers of on-site inspections? • How can cloud providers and cloud consumers respond to the challenge of the 'winners curse'? • What is the effect on network latency on cloud take up in areas of (s)lower connectivity, for example, parts of the less developed world? • Which forms of equivalence are driving the adoption of hybrid clouds? • What additional technological and managerial issues do hybrid clouds raise? • What impact might hybrid clouds have on future cloud services?
Variety	• How can the variety of a cloud service be evaluated? • How can variety be considered in designing cloud services? • How can users evaluate their need for variety? • Do the different levels of 'as-a-Service' products remain distinct and is this distinction valued by IT managers?
Abstraction	• At what level of abstraction is the largest growth in the market of cloud providers? • What role can third-parties such as system integrators play in managing variety and abstraction? • How should IT managers balance the desire for variety with the desire for abstraction?
Scalability	• What is the extent and nature of barriers to self-provisioning within enterprises and providers? • What cloud-systems development methods best support the move from application development to cloud-service development at scale? • What is known about the day-to-day operational challenges of managing large-scale data-centres?

that have operated large abstracted data-centres (e.g. Microsoft, Google and Amazon) a relative advantage over new entrants – a point Microsoft's Steve Ballmer made: 'We learnt from Bing about huge scalability of data-centres and this feeds into cloud applications where scale is important' (Ballmer, 2010b).

For software companies used to delivering software as a packaged product but moving to cloud, the ability to manage large data-centres and elegantly scale their software for large numbers of users is very new and challenging, a point made by one interviewee: 'In a traditional software world you might not need to worry about the performance of the service … you don't know the target hardware. It might be someone else's problem. When you're the provider, you're the one throat to choke' [i2].

For many interviewees an important consequence of adopting cloud was to provide a strategy 'for when they are going to sunset some of the existing on-premises technology' [i13], which can lead to cost savings and a reduced environmental impact. The cloud was simply a means of achieving this.

Our analysis of these technological dimensions of cloud desire raises a number of potential avenues for further research. These are outlined in Table 4.

Service dimension of cloud desires

As noted in the introduction, although the technological functionality offered by cloud computing is significant in the desire for cloud, for most adopters its potential is in the ability to transform organisations by driving down the overall cost of doing business, by reducing the cost and time needed to configure applications and by simplifying the overall process of integrating technology into the business process. This section therefore reviews the three key aspects of the service dimension of cloud desires.

Iyer and Henderson (2010) were among the first to present cloud computing as a shift in emphasis to service: 'With cloud computing and enterprises product-centric firm based model for applications and systems can be transformed to a global, distributed, service-centric model (where "service" means an IT service that the firm can use)' (Iyer and Henderson, 2010). Similarly Durkee's (2010) analysis incorporated service dimensions, defining cloud computing as the provision of computing 'services' on a demand-driven pay-as-you-go basis with little or no commitment. Indeed most authors discuss cloud 'as a service' available via the internet (Vaquero *et al.*, 2008; Buyya *et al.*, 2009a; Armbrust *et al.*, 2010; Stanoevska-Slabeva and Wozniak, 2010; Zhang *et al.*, 2010; Han, 2011; Marston *et al.*, 2011; Mircea *et al.*, 2011). Cloud can therefore be seen as extending the existing service concepts of web-services (O'Reilly, 2007) and ASP (Benlian and Hess, 2011).

Viewing cloud services simply in terms of the form of economic exchange associated with their consumption (Grönroos, 2011), whereby services are rented in contrast to more traditional assets that are procured, tends to emphasise the economic efficiency aspects of moving to cloud. However, a service dominant logic perspective towards cloud desires emphasises more generally 'the outcomes realised by customers instead of the process or act of provision to customers' (Vargo and Lusch, 2004) and is relatively less well understood (Bardhan *et al.*, 2010).

Table 5 Service dimension of cloud desires

Efficiency	The desire for a service that helps users to be more economically efficient.
Creativity	The desire for a service which aids innovation and creativity.
Simplicity	The desire for a service which is simple to understand and use.

The service dimension of cloud desire therefore sees cloud as more than just using the 'web as an alternative delivery and pricing mechanism for what used to be packaged software products' (Cusumano, 2010). Cloud service becomes the application of competencies (skills and knowledge on data-centre design and software innovations) through deeds, processes and performances (in particular the provision of equivalence, abstraction, requisite variety and scalability) for the benefit of the user. Elements within this service dimension are the extent to which cloud enables creative use of technology for business purposes, the simplicity by which such innovations are enabled, and the efficiency of such enablement (cf. Feiman and Cearley, 2009), as summarised in Table 5.

Efficiency

Much of the professional literature on cloud emphasises the efficiency savings that can arise from adopting cloud services and this was echoed by a significant number of interviewees. Cloud computing has often been marketed upon the belief that economies of scale offer significant cost reductions (e.g. Stevens, 2009; Hodges, 2011) and lower environmental impact (McKendrick, 2011) for equivalent computing, a theme also reflected in the academic literature (Armbrust *et al.*, 2009; Cubitt *et al.*, 2011; Marston *et al.*, 2011; Mircea *et al.*, 2011).

Interviewees provided evidence of efficiency improvements but also reflected some of the unease found in the literature as to whether certain enterprises with large data-centres could improve efficiency by adopting cloud services (Forrest, 2009). For much of the literature efficiency is seen as an attribute of a product, rather than a value-proposition which customers define the value of (Vargo and Lusch, 2004). Efficiency is therefore evaluated by customers based on their use of the service (Gray, 2008) and should include various hidden costs (Forrest, 2009). These include the cost of back-sourcing services if demands change (Sarkar and Young, 2011), and thus the risk of 'lock-in' to a service (due to switching costs) and the cost of managing the contract with the service provider.

Creativity

A key service desire is the extent to which cloud can enable creativity and innovation by lowering the transaction costs associated with innovation and enabling the development of value-networks.

Low friction creativity from cloud services

Experimentation is a key enabler of creativity and yet the traditional ways of managing computing infrastructures introduced delays due to the lead-time for provisioning and configuring which could take weeks or even months. 'The traditional way of [organisational IT Services] offering the fundamental services, just takes too long' [i13]. Cloud proponents argue that (as an interviewee stated) 'in this rapid pace of a global economy, if you can just cut that cycle down by a couple weeks or shrink it down to days, that translates into not just pure cost savings perspective but business opportunity that could be a competitive advantage' [i13].

It is argued that adopting cloud services can reduce the time taken to innovate and to bring innovations to market, since: 'you can turn on infrastructure very quickly and essentially bring new products to the market much faster' [i16]. Missing from this narrative however is whether such speed introduces pressure on IT departments to reduce the time for traditional planning, user requirements elicitation, and analysis activity and thus introduces new risks (Kautz *et al.*, 2007). It is however possible that cloud can reduce the risk of innovation as upfront commitments are lowered: you're 'able to make sourcing decisions when you need to make them, as you need to make them, in a rhythm that is much more attune to your business cycle '[i14]. Similarly a developer of solutions stated 'we can create global solutions cheaper, quicker and faster using the cloud than we ever could try and do using traditional media, traditional hardware' [i4].

Such optimistic views support Owens' (2009) assertion that 'elasticity could bring to the IT infrastructure what Henry Ford brought to the automotive industry with assembly lines and mass production: affordability and substantial improvements on time to market' and Boss *et al.*'s (2007) suggestion that cloud can improve the speed of new technology adoption.

For Marston *et al.* (2011) the ability to lower innovation costs means cloud computing exhibits the characteristics of distributive innovation (Christensen, 1997). As a result there are lower barriers to market entry and therefore previously excluded market participants (including emerging countries) (Goundar, 2010; Kshetri, 2010; World Economic Forum, 2010) and small- to medium-sized enterprises (Etro, 2009) will gain access to markets.

Creativity also emerges from the ability to exploit cloud services in 'a low friction way' [i14] allowing innovation because the technological functionality behind the scalability of cloud services allows the trialling of niche services in an agile manner with low risk (Weinhardt *et al.*, 2009). For example a supply chain optimisation company within the automotive industry can have its services 'plugged into' existing inventory systems. 'As those services become more robust you can use more of them. When you don't need them you can get rid of them and so on and so forth … [Cloud computing] should provide a platform for more flexibility and a platform for more innovation as more services become available' [i14].

Less clear is the extent to which enterprises have the skills and motivation to exploit such opportunities

(Ciborra, 1996). This question of willingness to transform in light of new technological opportunities has existed throughout the history of strategic information systems with technology either driving or following organisational changes (Porter, 1980; Hammer and Champy, 1993). 'Ready when you are … will be more of a function of how the organization absorbs the technology or solution is the gating factor to speed as opposed to the ability to implement the technology itself' [i14].

'Business agility' concerns an organisation's ability to appreciate and respond to change (Sambamurthy *et al*., 2003; Williams and Cockburn, 2003; Mathiassen and Pries-Heje, 2006; Zheng *et al*., 2011) and, together with speed to market are proving to be essential for business survival (Luftman and Zadeh, 2011). As a result there is a significant desire for agility (Sambamurthy and Zmud, 2000; Beck and Andres, 2005; Ågerfalk and Fitzgerald, 2006; Baskerville, 2006) characterised by quickness, nimbleness and lightness (Highsmith, 2002) and this is closely related to, and sometimes replaces, creativity: 'the real essence of cloud is flexibility and agility' [i16].

The time to provision that has hampered creativity has also been seen as a constraint on agility (Mircea *et al*., 2011). One interviewee recounted: 'The business pressure on a CIO today is not can this be done, it's how fast can we get this done. The compression in expectation is phenomenal … . So the benefit of the cloud that I believe brings is agility' [i19].

Emerging cloud value-networks for innovation

Brynjolfsson *et al*. (2010) suggests that 'computing is still in the midst of an explosion of innovation and co-invention. Those that simply replace corporate resources with cloud computing, while changing nothing else, are doomed to miss the full benefits of the new technology'. For them cloud provides services which must be exploited by companies in their innovation processes: 'it is the reinvention of new services which are key to the success of cloud' (Brynjolfsson *et al*., 2010). Central to this is the need to understand how portfolios of information services are brought together to support service provision to customers (Braa and Rolland, 2000; Mathiassen and Sørensen, 2008). While cloud provides services in an abstracted scalable form with varying levels of variety, such services typically need to be integrated, configured and reconfigured to enable the creative provision of service to customers. Services of higher variety and lower abstraction (such as Amazon EC2) are integrated in the provision of services of lower variety and higher abstraction (such as Dropbox.com or NetFlix.com), with various strategies for coordination (Demirkan *et al*., 2010).

This arrangement 'creates a setup that is typical in supply chains in logistical networks, insofar as end customers get their services from providers who in turn depend on other providers to efficiently provide that service' (Demirkan *et al*., 2010). This process of 'reconfiguration' (Normann, 2001) of the IT value chain is proving to not follow a simple linear co-ordination and reveals high levels of complexity. Leimeister *et al*. (2010) propose a focus on the emergence of 'cloud value networks' which emerge 'as some kind of marketplace, where various cloud computing resources … are integrated and offered to the customer'. Within these networks various types of participant are found (Leimeister *et al*., 2010).

Such a view reflects a service-oriented architecture perspective (Barros and Dumas, 2006) using cloud services just as globalisation has reconfigured product supply chains (Friedman, 2005). This approach can give rise to 'cloud ecosystems' (Shroff, 2010) – a term defined by Weinhardt *et al*. (2009) as 'the fruitful interplay and co-opetition between all players that realize different business models in the cloud computing context' (Weinhardt *et al*., 2009).

This was echoed in the interviews: 'as services become more plug and play it will be the ingenuity and the inventiveness of the client and the client's integrator … to be able to configure capabilities that will enable the client to do different things in different places than they've ever been able to do before' [i15].

A specific and important example of such creativity is the emergence of business intelligence through cloud computing (Mircea *et al*., 2011). This allows all sizes of businesses to exploit business intelligence across their processes (Creeger, 2009) and in collaboration with other businesses within their value networks. For example a clinical systems cloud supplier noted that by pooling clinical data in their servers it was possible to undertake real-time data analysis using the data from thousands of individual doctor's businesses held in the cloud – 'You need that data in the centre. You need big data for real time clinical profiling, which is the next generation of stuff, which is very clever, but nobody has cracked it yet' [i10].

Simplicity

Cloud computing involves the outsourcing of the skills and knowledge traditionally held by their IT department (such as configuring and managing servers), and organisations need to gain knowledge of how the outsourcer operates and how they ensure the service is provided as contracted. There are costs for enterprises in gaining such knowledge including the costs associated with the contractual arrangements that underpin the use of cloud services (Chesbrough and Spohrer, 2006; Lacity *et al*., 2011). Consequentially there is a desire that this knowledge exchange be as simple as is practicable.

Contracts for cloud services are becoming simpler by 'disentangling' (Callon, 1998) the complexity of the underlying hardware, for example by abstracting and by limiting the variety of a cloud service. The resulting simplicity can be reflected in simpler and more standardised contractual arrangement for the purchase of services by a larger number of customers. As one software company executive recounted: 'we had to condense that [contract] into a really digestible form … . To serve a volume market, you cannot have contracts of a thousand pages that you have maybe in a big outsourcing contract … . You need to have standardised contracts, very easy to understand, condensed down so that ultimately you could also sell solutions with these contracts over the internet' [i1].

Such standardised and simpler contracts for well-defined cloud services allow the use of simpler high-volume purchase channels such as credit cards (Tilson *et al*., 2010) with little or no direct interaction between user and provider (Armbrust *et al*., 2010; Durkee, 2010). Abstracted computing services are rented for a specific period of time in non-uniform patterns (supported by scalability). As the full cost of the service is included within this price the purchaser can avoid complex cost calculations (for software licences, hardware costs, support, power and cooling, ground rental etc.): 'if I want to set up a SQL server for five months, I can pay for a SQL server for five months and that covers the license costs for that five months … it simplifies our point of view' [i4].

This also reflects a consumerisation of IT services. Consumer-focused IT (such as Gmail, Dropbox and iCloud) are beginning to be employed within business (Moschella *et al*., 2004). Similarly, enterprise IT providers are packaging their services in a simpler structure – a consumerised 'retail model' which was pioneered by Amazon – 'essentially they welcome all comers and accept anyone who's got a credit card' [i7] (interestingly one interviewee described considerable difficulty when the owner of a credit card used to purchase Amazon cloud services left their company).

The value of simplicity

Simplifying the transactions increases simplicity as IT costs have traditionally been both hidden and complex (Ballmer, 2010b): 'the great thing about a pay-per-user model is that I can understand that, as a CFO. I can scope that and I know what my limits are and I know what my ceiling is' [i2]. For example power consumption, while negligible for an individual server, becomes significant for a large datacentre yet was traditionally excluded from IT cost calculations. 'We know a lot of IT departments don't pay for power. It's still a corporate cost and so it has to be factored in' [i18] and cloud services transparency over cost (including power) thus is beneficial for the CEO (though perhaps not for a CIO). As one interviewee stated: 'it starts to disaggregate IT as a utility charge [General and Administrative expenses] … It gives finance greater control, greater scrutiny over how [money is] being spent and who's spending it within the organisation, should they be spending that? … . Today, it's just this kind of black box' [i7].

The simplicity of cloud also reduces the need for administrators to manage servers and purchasing (Carr, 2005; Hamilton, 2008). 'That's the big play. It's turning infrastructure into something that's self-service and efficient and effective and mitigates risk by removing the need to have people managing it' [i18].

Similarly cloud providers, able to monitor usage patterns and demand through pay-as-you-go purchase, gain knowledge of market demand: '[when you] earn your business every quarter or every month … when subscriptions or renewals are due … it really aligns our entire business to the success of that project and the success of the customer' [i2].

The limits of simplicity: service level agreements

One area where simplification can make things harder for both contracting parties concerns equivalence. Traditionally for outsourced infrastructure the Service Level Agreement (SLA) contract provided knowledge of the quality of service expected comparable with internal service provision (Willcocks *et al*., 2011a). Such contracts were mechanisms for negotiating the relationship between IT vendor and client, establishing trust and anticipated risk (Czajkowski *et al*., 2002; Buyya *et al*., 2009b). At present, however, cloud SLAs are often weak and ineffectual for this purpose: 'In the cloud market space, meaningful SLAs are few and far between, and even when a vendor does have one, most of the time it is toothless' (Durkee, 2010). In part this is because many companies provide the same SLAs for all users: 'you can't buy your way to get a higher level of service availability … It's really a principle of our architecture … . Whether they are [a huge multinational insurance company] or a one person start up, gets the same level of service' [i2]. Part of this weakness in SLAs might be a consequence of service providers worrying about the unintended consequences of multiplexing large numbers of users on a single platform or server as this multiplies their risk of a breach of the SLA.

As a consequence SLAs are currently poor vehicles for customers to gain knowledge of equivalence and don't address the inevitable consequences of simplified contractual arrangements.

Having analysed cloud computing in terms of service a number of potential research issues emerge. These are outlined in Table 6.

Summary and conclusions: the desires framework

This paper has analysed cloud computing in terms of the features of the cloud that users desire. This analysis was based on a review of the literature and interviews with vendors and users. Through a synthesis of this evidence a series of research questions has been developed. The framework has two dimensions – a technological dimension (the desire for equivalence, variety, abstraction and scalability) and a service dimension (the desire for efficiency, creativity and simplicity).

We anticipate this framework being useful in aiding practitioners who are evaluating the potential of cloud computing for their organisation, comparing these desires with the reality of cloud services offered to them. Similarly, for researchers, the framework provides a means of comparing and evaluating cloud services within their research activity.

Our choice of the term 'desire' emphasises that cloud is currently difficult to exploit for many enterprises though they crave its benefits. While the allure of cloud relates to its efficiency, in reality many organisations have a poor understanding of their costs, cannot evaluate the benefit of cloud for their specific requirements and have limited ability to quantify the risks of making such a move. For such enterprises their legacy investments in IT, coupled with concerns about achieving equivalence in the cloud, make adoption difficult. We therefore believe that further research is needed to explore how organisations might evaluate equivalence of service within the cloud, how the cloud might demonstrate such equivalence (for example through standards), and thus how cost–benefit calculations might be undertaken.

Our choice of variety and abstraction as key technological elements of the desires framework highlights another research gap. The cloud computing literature has generally accepted a schism between SaaS, PaaS and IaaS. We hope that our spectrum of variety and abstraction will help researchers consider the relationship between these different forms of cloud service in more detail. Considering these spectrums leads us to believe that platforms

Table 6 Research questions from the service dimension of cloud desire

Efficiency	• To what extent are efficiency desires driving the adoption of cloud by organisations with existing data-centres? • What is the role of cost savings as the predominant organising vision for cloud computing? • How can organisations include consideration of the cost of back-sourcing in efficiency calculations?
Creativity	• What are the key enablers for enterprises to be able to experiment effectively with the options offered by cloud computing? • What management challenges arise when moving from cloud-based experimentation systems to full-scale production systems? • What are the defining characteristics of successful cloud ecosystems? • How might business intelligence applications drive business innovation in the cloud?
Simplicity	• How do cloud providers manage the tension between offering value-added services and operating in an increasingly commoditised marketplace? • What are the operational risks to enterprises of purchasing services on the basis of (over)simplified descriptions? • To what extent are Service Level Agreements proving useful for the selection and management of cloud services?

(PaaS) will emerge as the most relevant balance of variety and abstraction for most organisations alongside SaaS for generic activities such as email. Such platforms provide users with the ability to develop generalised components within a less abstracted computing model than SaaS, but without the complexity and limited abstraction of IaaS. PaaS brings the benefits of SaaS but with PaaS '… software development kicks in to build individual components or functionality to differentiate yourself' [i1].

One of the themes which emerged from our research was that of knowledge and trust. Like other outsourcing arrangements cloud computing demands trust, and to gain trust, knowledge of counter-parties is required. Contracts (and thus SLAs) form part of this knowledge exchange but have proved ineffective to date. Providers have tried standards (such as ISO security standards) and transparency measures but these do not cover the range of equivalence comparisons demanded. Similarly gaining knowledge of the variety of a service is often difficult as users have limited understanding of their demand for variety. We therefore believe research is needed to explore how each counterparty in a cloud relationship can gain better knowledge (and trust) of the other party.

Speed was also a key theme, emerging from the desire for agility and scalability. Yet the reality of cloud proved different from the hyperbole of rapidly provisioning near-infinite compute capacity. The capabilities of users and suppliers needs to match the agility demanded. Providers risk the 'winners curse' and must manage demand on shared resources. Similarly users risk pressures for accelerating their development practices and losing control over IT proliferation. Studying the impact of scale and agility on organisations who adopt the cloud seems an area ripe for research, as does the capabilities organisations require to effectively use the cloud.

Finally we identify creativity and innovation as a key driver for cloud computing. Cloud was used extensively within small start-ups and creative media companies we interviewed to innovate and work creatively. Further research is needed to explore how cloud computing (and thus the move to locate IT outside the enterprise) might enable more creative partnerships between organisations of all sizes.

Cloud computing has the potential to transform the way in which the IT function is provided in a large range of enterprises. The nature and speed of this transformation, however, is unclear. This paper has presented a framework of desires that seeks to structure the available evidence regarding the likely trends in cloud computing.

Notes

1 Commodity hardware is based on open standards (usually based on IBM PC architectures with Intel's x86 instruction set) purchased from generic suppliers. While lower in performance than specialised servers (such as those from IBM or Sun Microsystems) by using large numbers of servers such limitations can be overcome.

2 Minor edits have been undertaken on quotations to remove irrelevant words/phrases (e.g. 'um, err') and to clarify specialist terms and acronyms. Ellipses represent removed sections and square brackets represent addition or alteration for clarification. The overall meaning has not been altered and the utterances have been taken at face value with no attempt to interpret any possible hidden meanings behind them.

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Appendix

Research methods

We undertook over 50 semi-structured interviews with senior staff within a range of cloud-based organisations from across the supply chain between June 2010 and May 2012. We interviewed providers of cloud infrastructures and services, system integrators and users of cloud services. In terms of roles, we spoke to CEOs, CIOs, marketing managers and service directors. Interviews were normally undertaken by one person and were typically held over the telephone. They typically lasted an hour, with some running to over 2 h. Over 30 of these interviews were recorded and transcribed. A detailed analysis of the transcribed interviews was undertaken and the insights gained from the coding process were checked and challenged with the available literature and notes taken during other, non-transcribed, interviews.

The transcribed interviews were then coded by two of the authors. An inductive approach was adopted and no particular theory was identified *a priori* to frame and guide the data analysis although we drew heavily on our knowledge of IT outsourcing. In contrast through the analysis process a number of relevant concepts emerged which aided in making sense of the data. After much iteration, these ended up forming the desires framework presented above. Initially codes were used to simply classify each element ('quotations') of the interview. As the interviews were being coded, a parallel process of consolidation took place.

The first step towards consolidating codes into analytically distinct segments that can be examined together both within and between interviews involved tidying up the initial codes, for example by combining codes that covered the same concept but were labelled slightly differently. This process of analysis was based on and contrasted with themes from the cloud and outsourcing literatures which were being reviewed concurrently (Eisenhardt, 1989).

The process involved an iterative reading, coding and cycling through the codes. The validity of the coding and analysis was constantly checked by searching for counter examples and nuances in the text and codes. Through this process a series of higher-level thematic codes emerged.

Finally, a selection of the coded quotations was selected for use in the paper (Golden-Biddle and Locke, 1993). The selection process was guided by the need for a coherent narrative flow in the paper, so quotations that best illustrated the point being made were used. Other coded paragraphs would frequently feed into the underlying argument, even if they were not being directly quoted.

Limitations of this research

Despite being grounded in both the relevant literature and current empirical practice, the research has some limitations. As an attempt to categorise the complexity of existing, emergent practice, where different stakeholders may emphasise different aspects of cloud for their own purposes and where some have rebadged existing provision in terms of cloud, there will inevitably be some areas that are less well represented in the framework than others. We reflect on three such areas of under-representation below.

Potentially significant in this regard is the absence of a formal location for 'privacy issues'. We recognise that privacy and data protection issues are frequently cited as a reason for failing to move to the cloud and while there are a range of technological measures that can be resolved to address many of the existing privacy concerns, we subsume discussion of these within the equivalence desires of the framework. That is, what level of performance equivalence is required to satisfy data protection concerns and what consequences does this particular desire have on the particular form of cloud adoption (e.g. hybrid models).

Another important area of research relates to the skills necessary to manage cloud adoption within an organisation. For example, what kinds of architectural skill sets are required to link internal processes with the cloud, what sort of contract management skills are necessary to maximise the efficiency of cloud contracts?

Finally, cloud opens up challenging governance issues in terms of oversight of the cloud providers that an enterprise interacts with to deliver its business services.