Int. J. Business Information Systems, Vol. 10, No. 3, 2012 245

An empirical study of potentials of adoption of grid computing as a vehicle for tertiary institutions collaboration

Faith-Michael E. Uzoka*

Department of Computer Science and Information Systems,
Mount Royal University,
Calgary, Alberta, T3E6K6, Canada
E-mail: fuzoka@mtroyal.ca
*Corresponding author

B.A. Akinnuwesi

Department of Information Technology,
Bells University of Technology,
PMB 1015, Ota, Nigeria
E-mail: moboluwaji@gmail.com

S.O. Olabiyisi

Department of Computer Science and Engineering,
Ladoke Akintola University of Technology,
PMB 4000, Ogbomosho, Nigeria
E-mail: tundeolabiyisi@hotmail.com

Alabi Demilade

Department of Information Technology,
Bells University of Technology,
PMB 1015, Ota, Nigeria
E-mail: jennybym@yahoo.co.uk

Abstract: Grid computing is emerging as the foundation upon which virtual collaborations can be built among large organisations with the aim of integrating and sharing computer resources, and thus offering performance and resource availability, which is unattainable by any single institutional technology resources. With the level of increase in the number of tertiary institutions in Africa, and the attendant shortage of basic information technology resources, the use of grid computing for collaboration purposes would contribute to the enhancement of research, course delivery, course management, and other aspects of institutional development. This paper carries out an empirical study of the possibility of adoption of grid computing as a vehicle for collaboration among tertiary institutions in Nigeria from the perspective of the potential adopters (users) of the systems. This study also proposes a design and implementation framework for adoption of this technology by the tertiary institutions. The key challenges that significantly affect the adoption of grid computing in tertiary institutions are mainly attitudinal (perceived need and perceived benefits). Infrastructural issues (facilitating conditions) also impose limitations on the ability of universities to implement grid computing.

Keywords: grid computing; adoption; perceived needs; perceived benefits; university.

Reference to this paper should be made as follows: Uzoka, F-M.E., Akinnuwesi, B.A., Olabiyisi, S.O. and Demilade, A. (2012) 'An empirical study of potentials of adoption of grid computing as a vehicle for tertiary institutions collaboration', *Int. J. Business Information Systems*, Vol. 10, No. 3, pp.245–263.

Biographical notes: Faith-Michael E. Uzoka is a Faculty in the Department of Computer Science and Information Systems, Mount Royal University, Canada. He obtained his MBA in 1995, his MS in 1998 and his PhD in 2003, all in Computer Science with focus on Information Systems. He also conducted a two-year postdoctoral research at the University of Calgary (2004–2005). He is on the editorial/review board of a number of information systems and medical informatics journals/conferences. His research interests are in medical decision support systems, evaluation systems using soft-computing technology, organisational computing and personnel issues, and technology adoption/ innovation.

B.A. Akinnuwesi is an ABD (about to defend his PhD thesis) in Computer Science. He obtained his BSc in 1998 and MTech in 2003, both in Computer Science. He is the Director of the Computer Centre at Bells University of Technology, Ota, Nigeria. He was a Visiting Research Scholar at ICITD, Southern University, Baton Rouge, Louisiana in 2010. He has published in a number of reputable journals and conferences. His research interests are in system performance evaluation using soft-computing techniques, user involvement and organisational issues in system development, expert system and software engineering.

S.O. Olabiyisi received his BTech, MTech and PhD in Mathematics from Ladoke Akintola University of Technology, Ogbomoso, Nigeria, in 1999, 2002 and 2006 respectively. He also received his MSc in Computer Science from the University of Ibadan, Ibadan, Nigeria in 2003. He is a Lecturer at the Department of Computer Science and Engineering, Ladoke Akintola University of Technology, Ogbomoso, Nigeria. He has published in reputable journals and learned conferences. He is a member of the Computer Professional (Registration) Council of Nigeria (CPN). His research interests are in computational mathematics, computational complexity, theoretical computer science, simulation and performance evaluation.

Alabi Demilade is a graduate of Information Technology, Bells University of Technology, Ota, Nigeria. She concluded a one year NYSC in Information Technology. She is currently an IT Practitioner in Lagos, Nigeria.

1 Introduction

Advances in internet and the availability of powerful computers and high speed networks are changing the landscape of large scale parallel and distributed computing. These technology advances have allowed the use of distributed resources as a single and powerful virtual machine, leading to what is popularly known as grid computing.

Research-oriented organisations and universities practicing in advanced research collaboration areas require the analysis of tremendous amounts of data. Grid computing provides mechanisms for resource sharing by forming one or more virtual organisations providing specific sharing capabilities. Such virtual organisations could resolve specific research problems with a wide range of participants from different regions of the world. Grids make a large number of computing resources, data stores, analysis and visualisation tools available to analysts and collaborators in a coalition environment for decision support and related applications. Besides the advantage of accessing locally unavailable resources, the grid is usually also expected to utilise the existing resources more efficiently. Grid computing is not only a mainstream computing paradigm for resource intensive scientific applications but it also promises to become the future computing paradigm for enterprise applications.

In times of global economic slow-down, organisations are increasingly under pressure to cut down their budget. With significant advances in and impact of information and communications technology (ICT), there is an increasing perception of computing as the fifth utility – after water, electricity, gas and telephone (Rajkumar et al., 2009). Grid computing is one of the computing paradigms that would utilise the power of computing in propelling everyday lives. Grid computing and server consolidation are two aspects of computing that could assist organisations in reducing their budgets on computing facilities. Server consolidation process focuses on reducing the physical number of computers and moving the workloads/applications running on them to a smaller set of computers, while still maintaining service level objectives. Grid computing tries to utilise the existing computer infrastructure to create a virtual computer that has higher computational power (performance rating) than any single computer. Grid technology can aggregate all the powers from the CPU's of participating organisations to generate a super computing power that will help users to access various types of services simultaneously (Foster et al., 2001).

Grid computing is a resource sharing platform that presents a new trend in distributed computing and internet applications. It can construct a virtual single image of heterogeneous resources, provide uniform application interface and integrate disparate computing resources into a completely ubiquitous and transparent aggregation (Jin, 2004). Grid computing has impacted on the development of some resource sharing technologies, such as cloud computing and heterogeneous distributed systems (Zhang et al., 2010). Grid computing enables organisations (real and virtual) to take advantage of underutilised resources to meet business requirements while minimising additional costs. The nature of a computing grid allows organisations to take advantage of parallel processing; making many applications financially feasible. Grid computing makes more resources available to more people and organisations while allowing those responsible for the IT infrastructure to enhance resource balancing, reliability, and manageability. It has the potential of reducing maintenance cost and improving overall performance without significant hardware changes. It could if done properly, reduce the complexity infrastructure, the cost of maintenance as well as increase the efficiency of the utilisation of computing resources.

The higher educational sector is gradually moving from the individualistic model to a highly collaborative model as universities continue to seek rational opportunities for managing resources. The economic recession of 2008/2009 has brought a new sense of reality in higher education, with dwindling governmental funding for research and learning. It is argued (Sultan, 2010) that cloud (and grid) computing would be one of those opportunities sought by cash strapped educational establishments. Apart from the recent economic realities, the development of the internet, Web 2.0, and other communication technologies has brought about knowledge integration and dissemination in a seamless manner. Universities are gradually tending toward a meta-university system. Wheeler and Waggener (2009) suggest that this meta-university is already emerging, based on a consortium sourcing model that provides a generalised template for like minded interests to opt-in to efficiently aggregate demand and coordinate research and educational resources.

This study focuses on the factors affecting the adoption of grid computing for collaboration and resource sharing by universities a developing country context. A number of cooperate organisations (especially in the developed world) have taken advantage of grid computing. As with most technology adoption, developing countries (especially in Africa) have lagged behind. The e-readiness levels of these countries are low (McKenna, 2006), and inadequacy of facilitating conditions could hinder the adoption of technology such as grid computing. The rest of the paper is organised as follows: Section 2 presents a review of some relevant literature on grid computing technology and adoption. In Section 3, the framework for the research is presented, while the methodology adopted in the study is described in Section 4. The analysis of data is carried out in Section 5, while the results are discussed in Section 6. Some conclusions are drawn in Section 7

2 Literature review

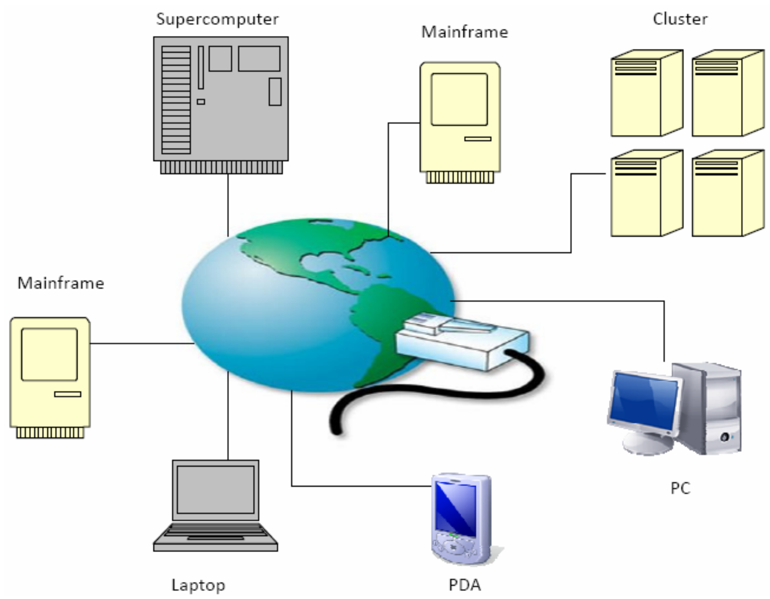
Grid computing is the aggregation of distributed and heterogeneous autonomous computing resources connected by a network into one large virtual system. The large-scale virtual system is redistributed as needed by the end users. Examples of the computing resources are: processor, storage, data, hardware, software, telecommunication facilities, and personnel. Grid computing technology dynamically connects remote computers and computing resources over the internet or a virtual private network. It focuses on increasing computing power, defined computational capabilities, coordinating the sharing of resources, and solving problems in multi-level virtual organisation (Heather and Benn, 2004; Manvi and Birje, 2010; Oracle Corporation, 2009).

In Oracle Corporation (2009), the detailed description of the basic technology principles on which grid computing operates is presented. The technology principles are: standardisation of hardware and software components to reduce incompatibility of system components and simplify configuration and deployment of available resources; virtualisation of ICT resources by pooling them into shared resources; and automation of systems management which includes resource provisioning and monitoring. The application of grid computing architecture enables organisations to create a large-scale computing infrastructure from inexpensive, off-the-shelf components. Other benefits of grid computing are: quick response to volatile business needs; real-time responsiveness to dynamic workloads, predictable ICT service levels, and cost reduction as a result of improved efficiency and smarter capacity planning (Oracle Corporation, 2009). With the aid of the distributed system of computers, computing workload can spread across and the grid users can take advantage of the enormous ICT resources in the grid.

Grid technology is well applied in electric power system where power grid is established. Thus, consumers of electricity do not need to know anything about what stays beyond the socket. The consumers can utilise all the electricity they want but this is subject to the agreement with the electrical society or company. Today grid computing has attracted global attention in a variety of application domains such as environment, chemistry, aerospace, physics and healthcare systems (Pin et al., 2007; Lingfen and Emmanuel, 2005). Grid computing is designed to achieve the following objectives (Kentaro et al., 2005; Foster and Kesselman, 2004): sharing of distributed and heterogeneous computing resources belonging to different organisations; exploitation of underutilised resources; enablement and simplification of collaboration among different organisations; provision of login service with secure access to grid resources and ensure security in remote sites; provision of resource management; secure data transportation; and provision of quick and accurate results.

Figure 1 presents a conceptual diagram of the architecture of grid computing that provides links to remote institutions and end users via wired and wireless networks. This is a basic architecture on which other models of grid computing in various problem domains are built. Grid computing components are classified into: resource management (this includes uniform, scalable mechanisms for naming, locating and allocating computational and communications resources in distributed systems); application-development environments (this entails the integration of grid services into existing frameworks, environments and languages); data management and access; information services; and security.

Figure 1 Conceptual diagram of grid computing architecture (see online version for colours)



Source: Kumar et al. (2008)

Grid-based collaborative learning approach is the facilitation of learning through the provision of shared ICT systems that are connected using the internet and web technologies. It provides the platform to create a pool of the teaching and learning resources available in various academic institutions, as well as the resources available in various industries that have linkages with the academic institutions. It offers a complementary platform for students to conduct additional learning activities out of the classroom, and also for working adults or other non-regular students to learn, based on their own individual schedules. Grid-based learning is expected to be a strong support to traditional education system. It provides convenience to the students in terms of time and space, and improves the efficiency of the educators and as a result, supports more students' participation, timely updates of course or subject materials, and online assessments (Li et al., 2008).

A number of research works have been done on the development of grid computing architecture for institutional collaboration in order to facilitate electronic learning. For example, Victor and Gottfried (2003) gave a detailed outline of a proposed architecture for e-learning grid which integrates core grid middleware and learning management system (LMS) functionality appropriately. The objective was to draw up a research agenda for the exploitation of grid computing in e-learning. The advantages derived from grid computing and the applications that could benefit from it are presented. In Yang and Ho (2005), data grid technique is proposed to connect idle storage devices on campuses. This serves as substitute for expensive storage devices, such as disk arrays, and as e-learning platform storage devices. Thus, schools with insufficient budgets can obtain better services and vast teaching resources using the data grid learning technology. In Choo et al. (2007), a learning community network, EGRID is proposed to create a global network for users in the e-learning community to interact and to participate in the educational process. The paper highlights the grid architecture used and the key features of the grid. Other forms of grid-based collaborative learning models are presented in the following works (Leila et al., 2007; Contreras and Murtagh, 2005; Marc et al., 2005; Maozhen and Marios, 2008; Jukniute and Paulikas, 2007; Nabil, 2010; Saleh, 2010). Resource discovery is an important function of e-learning, thus Boon et al. (2006) describe the development of such resource discovery services as part of an initiative to pilot e-learning and a shared digital library infrastructure for grid computing training projects in Europe.

2.1 Development, implementation and adoption issues

Grid computing is faced with some development, implementation and management challenges. In Heather and Benn (2004), these challenges are classified as: technical, organisational and strategic challenges. Though the vision of grid computing is promising, but the challenges of managing grid infrastructure are daunting. Some of the difficulties include the heterogeneity of devices on the grid; the need to operate in geographically dispersed and complex environments; the unpredictability of system performance and behaviour over time; and the existence of multiple administrative domains. There are also concerns about usage pricing, service-level agreements and network-security issues. These challenges include: measuring the efficiency of grid computing for collaborative learning system (Paul et al., 2010); measuring the performance, reliability and scalability of grids (Omid et al., 2006); improving trust and security in grid (Amit et al., 2010; David et al., 2010); resource usage policy expression and enforcement (Jun et al., 2007); efficient access to many small files in a file system for grid computing (Douglas and Christopher, 2007); efficient anonymity protocol for grid computing (Souvik and Zhao, 2004); pricing information service (Alexandru and Jörn, 2007); end-to-end accountability (Elisa et al., 2008); and implementation of system policy derived from the interactions between service level agreements (Bradley and Hanan, 2005).

A number of authors have studied the adoption of grid technology by corporate organisations (e.g., Lim, 2010; Manvi and Birje, 2010; Oracle Corporation, 2009; Lingfen and Emmanuel, 2005; Li et al., 2008; Maozhen and Marios, 2008; Nabil, 2010; Saleh, 2010; Paul et al., 2010). Despite the benefits derivable for grid computing adoption, there is still a low level of adoption of grid technology due to some reasons explained in Table 1.

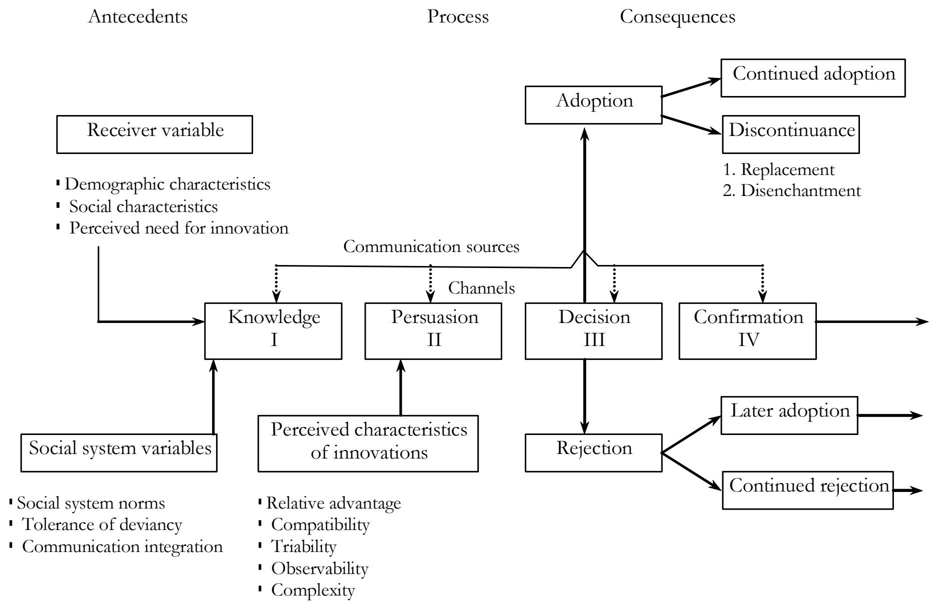
Table 1 Grid computing adoption factors

Author(s)	*Grid computing adoption factors*
Earl and John (2004)	Inability of users to understand how grid can fit in their environments. In this way, grid runs the risk of underwhelming users and because grid is still largely undefined, users run the risk of adopting a vision that ultimately remains unfulfilled.
Ramkumar (2009)	Factors considered are mainly from the perspective of consumers/users of grid computing service rather than from the perspective of providers/vendors of grid services. For example, the demand for using grid computing services, frequency of usage, stage of consumers' line of business. The authors also emphasise that the decision to adopt and use grid computing services in an enterprise is a major strategic decision, which involves both objective and subjective decision making process.
Joseph et al. (2004)	Complexity of the IT infrastructure required to implement a grid, the complexity of IT integration across heterogeneous environments, enabling grid resources in homogeneous and heterogeneous environments, enabling resources as services to grid partners, and enabling virtualised applications to grid partners, and ability of grid technology to deliver increased business value
Won et al. (2009)	Security of computer system and data stored on them, performance measured in terms of communication time between the client computer and the web server in the grid, compliance to some government regulations regarding the secure storage, privacy, and disclosure of data, harmonising the functionalities of private grids and resolving possible conflicts, integration of applications and data on multiple public grids, cost of development, implementation, management, and remote administering of computing resources
Subhas and Arka (2011)	Size of the IT resources in the organisations, the organisations' utilisation pattern of the resources, sensitivity of the data the organisations are handling, and criticality of work done by the companies.
Christian (2010)	Size of the IT department of the organisations, management-related innovativeness and organisation employee-related innovativeness, open-mindedness of the management and employees of the organisations about new practices, trust, uncertainties about new technology, and coercive pressure from suppliers, customers, or parent companies can exert pressure on organisations to adopt grid technology.
Gridbriefings (2008)	Standardisation which translates to interoperable, rapidly changing marketplace (this makes it hard to pin down a strict standard).
Foster et al. (2001)	Lack of viable business models that can make organisations to gain economically from the grid market could result in non-adoption.

3 Research framework

This study utilises the diffusion of innovation model (DOI). The DOI model (Rogers, 1983) sees innovations as being communicated through certain channels over time and within a particular social system. Similar to the DOI model is the technology acceptance model (TAM) (Davis, 1989), which places emphasis on subjective/psychological predispositions and social influences on behavioural intention to adopt a new technology. A similar theory is the theory of planned behaviour (TPB) (Ajzen, 1991), which identifies three factors that influence consumers' acceptance of new products; namely: attitude, subjective norms and perceived behavioural control.

Figure 2 DOI model



Diffusion studies have focused on the following five elements: the characteristics of an innovation, which may influence its adoption; the decision making process that occurs when individuals or organisations consider adopting a new idea, product or practice; the characteristics of individuals/organisations that make them likely to adopt an innovation; the consequences of adopting an innovation; and communication channels used in the adoption process. According to Rogers (1995), the perceived attributes of innovation are:

a *relative advantage:* the degree to which an innovation is perceived as being better than the idea it supersedes

b *compatibility:* the degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters

c *complexity:* the degree to which an innovation is perceived as relatively difficult to understand and use

d *triability:* the degree to which an innovation may be experimented on

e *observability:* the degree to which the results of an innovation are visible to other

The DOIs theory suggests that the different dimensions of attitudinal belief toward an innovation can be measured. In general, perceived benefits of an innovation are positively related to its rate of adoption (Rogers, 1983). Previous research has also indicated that an innovation with substantial complexity requires more technical skills and needs greater implementation and operational efforts to increase its chances of adoption (Cooper and Zmud, 1990). Rogers (in Tan and Teo, 2000) argues that potential adopters who are allowed to experiment with an innovation will feel more comfortable with the innovation and are more likely to adopt it.

The DOI model provides a useful framework for studying innovation at organisational levels. The DOI emphasises the influence of receiver variables, social system variables, and perceived characteristics of innovation as determining factors for adoption of technologies. We posit that the adoption (or non-adoption) of grid computing for collaboration among universities in Nigeria can be understood in the light of these three factors, which constitute the basis of our research hypothesis.

3.1 Receiver variables

The DOI model recognises organisational demographic characteristics, social characteristics, and perceived need for innovation as important variables that could present controlling effects on the organisation's intention to adopt technology. Our study considers perceived need for grid technology as a major factor that could influence the adoption of grid by Nigerian universities. Determining the amount of training received by Faculty and staff of the universities would provide insight into the level of knowledge of grid computing and consequently, the perceived need for grid. Equally, demographic variables such as age of organisation could be useful in explaining grid adoption intention. H_1 relates to the receiver variables and is states as follows:

H_1 The perceived need for a facility (such a grid computing) would prompt decision makers to adopt the technology.

3.2 Perceived innovation characteristics

The DOIs theory suggests that the different dimensions of attitudinal belief toward an innovation can be measured using the following perceived attributes; namely: facilitating conditions, perceived benefits, compatibility, complexity, triability, and observability. In general, perceived benefits of an innovation is positively related to its rate of adoption (Rogers, 1983). Previous research has also indicated that an innovation with substantial complexity requires more technical skills and needs greater implementation and operational efforts to increase its chances of adoption (Cooper and Zmud, 1990). In our factor analysis, complexity did not produce an eigenvalue that was significant for analysis. Therefore, complexity was excluded in our hypotheses. The following four hypotheses relate to innovation characteristics:

H_2 The perceived benefits derivable from the use of grid computing would be a key factor in the decision to adopt grid computing in universities.

H_3 Availability of facilitating conditions such as computing facilities, network infrastructure, and power supply would positively affect a university's ability to adopt grid computing.

H_4 The compatibility of a given technology with existing systems would increase the chances of its adoption.

H_5 The adoption of grid computing by Nigerian universities is influenced by the existence of grid computing in other situations (sectors) in the country.

3.3 Social system variables

Social system variables are important moderators in the adoption decision. This is because the organisation is a social system and for most members of a social system, innovation decisions depend heavily on the innovation decisions of the other members of the system (Rogers, 1995). Hypotheses H_6 and H_7 relate to social system variables.

H_6 Grid computing would be adopted if it is perceived to enhance inter-institutional communication

H_7 The extent of tolerance to deviancy would significantly influence an organisation in deciding to adopt a new technology, which may be a deviation from the known systems.

4 Methodology

4.1 Sampling scheme

The sampling method was random judgment sampling. Fifteen universities were randomly chosen from a population of 104 Universities in Nigeria. The list of universities was obtained from the National Universities Commission (http://www.nuc.edu.ng/pages/universities.asp). The universities chosen included federal, state, and private universities. Ten questionnaires were administered to staff of the randomly selected universities using purposeful sampling. The questionnaire was distributed to management (academic and administrative) and information technology (IT) staff of the universities. These categories of staff are likely to be responsible for taking decisions on the adoption of major technology facilities.

4.2 Instrument

The data gathering instrument used in the research was the questionnaire. A total of 150 questionnaires were distributed to the 15 universities that constituted the sample for this study. One hundred and two of them were properly filled and used for analysis purposes. This represents 68% response rate. The questionnaire consists of two sections. The first part summarises demographic information including information on availability of grid computing supporting infrastructure, and implementation of full grid computing. The second section of the questionnaire measured variables relating the DOI model that could affect the adoption of grid computing. An empirical study of potentials of adoption The items were measured on a five-point Likert type scale (from 1 = strongly disagree to 5 = strongly agree).

4.3 Processing

Descriptive statistics were employed in the presentation of data obtained from the first section of the questionnaire. The next part of the analysis involved the use of exploratory factor analysis to reduce the variables into a small number of factors that could have an effect on the adoption of grid technology in universities. The reduced factors were used as explainable factors that can affect the adoption of grid computing. The factor analysis was carried out using the statistical package for social sciences (SPSS) for Windows Version 17.0. The factors were extracted by principal axis factoring and rotated using varimax with Kaiser normalisation method to maximise the relationship between the variables and some of the factors. The Kaiser-Meyer-Olkin normalisation (KMO) measure of sampling adequacy indicates the suitability of the application of factor analysis for exploratory purposes (KMO measure = 0.710). The Bartlett's test of sphericity was used to confirm the adequacy of the sample (χ^2 = 1,004.762, df = 210). Finally, multiple regression analysis was used to test the hypotheses relating to the factors that affect implementation of grid technology.

5 Data analysis

The data were collected from university management and IT personnel. Table 2 depicts the demographic characteristics of these respondents.

Table 2 Respondents characteristics

Variable	*Value*	*Percent*
Respondents gender	Male	74.5
	Female	25.5
Respondents age	≤ 30	40.2
	31-50	52.0
	> 50	7.8
Respondents department	Administration	15.7
	Academic department	30.4
	Information technology	23.1
	Others	30.8
Age of organisation (years)	0–5	44.1
	6–10	22.5
	11–15	14.7
	≥ 16	18.6
Management level	Senior management	24.5
	Middle management	51.0
	Others	24.5
Responsibility for IT facilities decision	Management	21.6
	IT department	29.4
	Management in conjunction with IT	49.0

Majority of the respondents were males (74.5%) and also less than 50 years of age (92.2%). This gender and age bracket defines the demographics of IT personnel cum management in Nigeria. Most of the IT and management positions are occupied by males, and Nigerian universities are increasingly employing younger people into management positions. Management staffs that were surveyed were mostly heads/chairs of departments, deans of schools, and top academic management (30.4%). Administrative management constituted 15.7% of respondents, while the IT staffs were 23.1%. Most of the universities were new (less than five years), which could point to the randomness of sampling tilting more to newer (private and state) universities. In most of the universities (49.0%), the responsibility of deciding to adopt a major IT facility (such as grid computing) lies with management in conjunction with the IT department.

Table 3 presents the frequency of grid computing training undergone by university staff, while component analysis of grid (and grid-related) computing implementation is shown in Table 4. From Table 3, it is observed that most universities (61.8%) never provided any form of training/awareness on grid computing to its staff. This is a reflection of low adoption intention. Table 4 shows that internet connectivity and security of systems are at fairly above average levels of 3.3235 and 3.2843 respectively on a scale of 1–5, while collaboration among universities is either at an average or below average level. Collaboration is measured in terms of: sharing of educational resources using ICT (3.0882), and computer network-based communication (2.8922). Implementation of full grid system is at below average level of 2.6765.

Table 3 Frequency of training on grid computing

	Valid percent	*Cumulative percent*
Every three months	17.6	17.6
Every six months	12.7	30.3
Every year	7.9	38.2
Never	61.8	100
Total	100.0	

Table 4 Implementation of grid-related computing

S/N	*Performance index*	*Mean*	*Standard deviation*
1	Connectivity of systems across departments via computer network	3.3235	1.15323
2	Communication between the institution and other institution via computer networks	2.8922	1.21791
3	Sharing of academic resources between the institution and other institutions using information and communication technology	3.0882	1.29051
4	Security of existing institutional network	3.2843	1.17210
5	Implementation of a full grid system	2.6765	1.31376

Table 5 shows the exploratory factor analysis of variables affecting the adoption of grid computing. Forty variables were initially included in the survey to test the hypotheses relating to the DOI model. After three iterations, a total of 19 variables were dropped from the model either due to low communality or non-factor loading. Thus, 21 variables were included in the analysis. The extraction method found to produce the most meaningful factor structure was principal axis factoring while varimax rotation with Kaiser normalisation was adopted.

The 21 variables loaded on seven distinct factors. The factors are indicated, including their eigenvalues, percentage contributions to the variability of data, variables that loaded on each factor, and Chronbach's *α* values indicating reliability/internal consistency of data. Two factors that had single variables were retained due to the high factor loadings and incompatibility with other factors. Though the eigenvalue rule (engenvalue ≥ 1) was adopted, in factor extraction, the scree plot also pointed to seven factors. Thus, the hypotheses were reformulated based on the factor loadings.

Table 5 Factor analysis

Factor	*Eigenvalue*	*Variance explained*	*Variables*	*Factor loading*	*(α)*
Perceived benefits	3.356	15.981	Resourcefulness of grid computing	.854	0.862
			Enhancement of job satisfaction	.783	
			Enhancement of motivation and efficiency	.760	
			Essential for the institution	.700	
			Relevance to networking	.488	
Perceived need	2.340	11.142	Existence of grid computing in other schools	.704	0.791
			Attitude of management to grid computing	.586	
			Awareness of grid computing	.546	
			Number of participating institutions	.514	
			Training exposure on grid computing	.492	
			Relevance of grid computing awareness	.489	
			Acceptability of grid computing	.426	
Communication	1.788	8.194	Effective means of communication	.797	0.744
			Time savings	.630	
			Improvement of communication	.521	
Facilitating conditions	1.389	6.249	Adequacy of facilities	.779	0.516
			Power supply	.524	
			Grid computing permits laziness	.813	
			Anxiety about grid computing	.591	
Compatibility	1.389	6.614	Accessibility to other institutions resources	.607	1
Observability	1.083	5.159	Utilisation of grid computing in other sectors	.609	1

For the purpose of testing the hypothesis, a regression analysis was carried out. Full implementation of grid computing was used as the dependent variable, while the extracted factors constituted the independent variables. The model had a fair predictive ability (R^2 = 0.309). The ANOVA test produced an *F* value of 6.009 and a significance of

0.000, indicating a significant global influence of the extracted factors on grid computing adoption. The regression statistics is shown in Table 6. The *t*-values indicate that *perceived benefits*, *perceived need*, and *facilitating conditions* have statistically significant predictive capability. In other words, these factors exert a significant influence on the adoption of grid computing by Nigerian universities. The standardised beta coefficients indicate that the *perceived need* exerts the highest significant influence ($\beta = 0.404$, $t = 4.694$, $p = 0.00$) followed by *facilitating conditions* ($\beta = .258$, $t = 2.992$, $p = .004$) *and* lastly *perceived benefits* ($\beta = .213$, $t = 2.470$, $p = .015$). Thus, H_1, H_2, and H_3 are supported, while H_4, H_5, H_6 and H_7 are not supported. Therefore, *compatibility*, *observability*, *communication*, and *tolerance to deviancy* do not have significant impact on the adoption of grid computing by Nigerian universities.

Table 6 Regression statistics

Model		*Unstandardised coefficients*		*Standardised coefficients*	*t*	*Sig.*
		B	*Std. error*	*Beta*		
1	(Constant)	2.676	.112		23.881	.000
	Perceived benefits	.295	.120	.213	2.470	.015
	Perceived need	.586	.125	.404	4.694	.000
	Communication	.023	.127	.016	.182	.856
	Facilitating conditions	.380	.127	.258	2.992	.004
	Tolerance of deviancy	–.077	.131	–.051	–.590	.557
	Compatibility	.178	.120	.128	1.484	.141
	Observability	–.052	.132	–.034	–.394	.694

Note: [a]Dependent variable: implementation of full grid

6 Discussion of results

An e-learning data grid of all technical and human resources of universities in Nigeria with all their resources fully shared and accessible would minimise the problems of insufficient technical resources and dearth of teaching staff in the universities. Table 3 shows that 61.8% of the universities never made provisions for training/awareness programmes on grid computing for staff and students. In addition, the *t*-value (Table 6) shows that *users perceived need* ($\beta = 0.404$, $t = 4.694$, $p = 0.00$) for grid technology is a significant factor for adoption. The inability of users to understand the concept of grid and how it fits to their work environment is a major factor affecting the adoption of technology (Uzoka and Nzinge, 2009). Grid computing is largely undefined in the Nigerian tertiary institutions.

Furthermore, the poor knowledge of the users about grid prevents them from perceiving the various benefits attached to it, particularly for teaching and learning. This is reflected in the results presented in Table 6 with *perceived benefits* having ($\beta = .213$, $t = 2.470$, $p = .015$). In the real sense, people will like to embrace any technology that they know about its benefits to them. Nigerian tertiary institutions are yet to have a full understanding of the extent to which grid system could facilitate research, teaching, learning and resource sharing. In Earl and John (2004), poor organisational (consumer) demand for grid services and infrequent usage is attributed to inability of the organisations or consumers to visualise the merits of using grid services.

Our result also shows *facilitating conditions* (β = .258, t = 2.992, p =.004) as another significant factor affecting the adoption of grid technology in the universities. Facilitating conditions such as electricity, ICT equipment (such as internet access, bandwidth size, software, personal computers, communication cables, routers), ergonomics facilities (such as lightings, air conditioner, furniture, etc.), and security facilities (e.g., firewalls) are expected to be adequate for grid system to work efficiently. A number of these conditions seem to be poorly developed in most developing countries such as Nigeria. Facilitating conditions have been identified in Won et al. (2009), Christian (2010), and Subhas and Arka (2011) as significant for grid technology adoption.

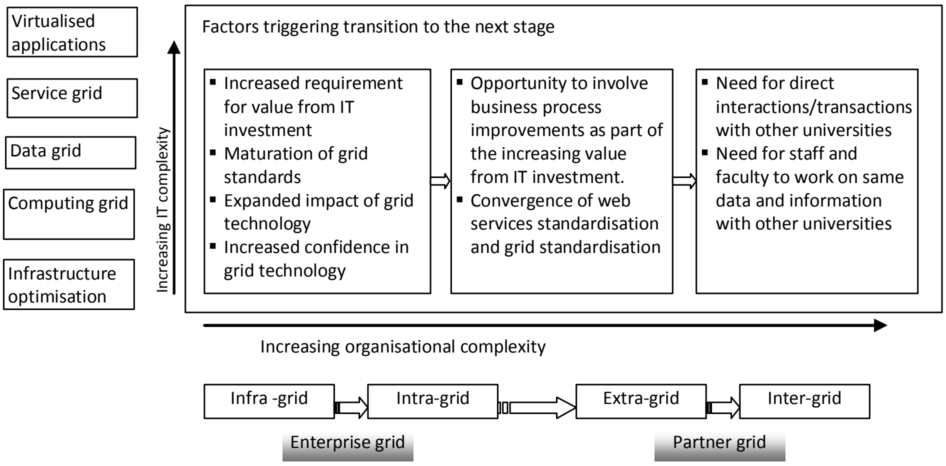
Our result did not find *communication* as a significant influence on grid computing adoption because most respondents did not know much about grid computing and its benefits. The communication aspects of adoption (including the impact of grid on communication) are largely unknown by the potential adopters. In addition, with grid technology largely undefined in the Nigerian tertiary institutions, *tolerance to deviancy* will not be a significant factor to grid technology adoption. This is because a large population of the people in the institutions are not aware of it and as such, would not be anxious about its impact on their job performance and productivity. Since several people are not aware of grid technology, then *observability* will not be a significant factor for adoption of grid technology.

7 Conclusions

Grid computing is an emerging technology in the private and public sectors today. It is capable of enabling high-performance in environments where emphasis is on agility and the ability to optimise resources allocation. In this paper, we examined variables that will impede the adoption of grid technology in Nigerian universities. After three iterations, we were left with 21 variables that were included in the analysis and these variables were loaded on seven distinct factors. The t-values from the regression statistics indicate that *perceived benefits*, *perceived need*, and *facilitating conditions* exert a significant influence on the adoption of grid computing by Nigerian universities. The standardised beta coefficients indicate that the *perceived need* exerts the highest significant influence (β = 0.404, t = 4.694, p = 0.00) followed by *facilitating conditions* (β = .258, t = 2.992, p = .004) and lastly *perceived benefits* (β = .213, t = 2.470, p = .015). Our result shows that *communication*, *tolerance to deviancy*, *compatibility*, and *observability* do not have significant impact on the adoption of grid computing by Nigerian universities.

In order to take advantage of the benefits associated with collaborative grid, management of universities need to invest in awareness programmes, workshops, and acquisition of grid resources. Grid computing relies on a number of existing technologies such as the internet, virtualisation, and reliable systems with reasonable computing power. In addition, universities need to work out a trust model for implementing grid technology. Three kinds of distributive computing trust models are identified in Sangroya et al. (2010). These include direct trust, transitive trust, and assumptive trust. In a grid computing environment, transitive and assumptive trusts are critical because of the inter-organisational exchange of data and programmes. Direct trust would be useful in a cloud paradigm where the cloud provider is the common trust entity that performs all original entity authentications and the generation of credentials that are bound to specific entities. Factors triggering transition to the next stage Nigerian universities could evolve into a virtual meta-university with the adoption of grid technology. A four step, two tier model is proposed for such collaborative integration based on an adaptation of the model presented in Joseph et al. (2004), which recognises *enterprise grid* and *partner grid*. Figure 3 shows a proposed grid model for Nigerian universities. In the proposed model, a transition is proposed from the enterprise grid to the partner grid.

Figure 3 Grid model for universities



At the level of the enterprise grid, universities can adopt infra and intra grids. Infra grid enables optimisation of resource sharing within departments in each faculty/school of the university. This provides a well controlled environment with defined business policies, integration and security requirements. The intra grid would enable a more complex resource sharing among faculties/schools within the university. This type of grid would provide a valuable experience in dealing with the more complex data security, data sharing, and required resource sharing policies. Such 'campus' grids would provide impetus for collaboration at an external level.

The partner grids proposed for the university system would be defined at two levels – homogeneous level and heterogeneous level – in terms of the statutory objectives of the university. The universities in Nigeria could be categorised broadly as conventional universities, universities of technology, and universities of agriculture. The universities in each category have some homogeneity in terms of statutory objectives, research interests, teaching, and learning needs. Universities with some levels of homogeneity could form extra-grids, while the last stage would involve the collaboration of different extra-grids in an inter-grid configuration.

In implementing the model proposed in Figure 3, a data classification scheme is vital (Kurta, 2010) along the lines of the categorisation of the university in terms of objectives, teaching, and research. Furthermore, universities should determine the extent of IT services that can be aggregated and why (Wheeler and Waggener, 2009). Based on the roadmap in Educase and Nacubo (2010), the following could be utilised by universities as the roadmap for commencement of grid adoption:

1 create a map of grid space
2 create campus grid computing roadmap
3 publish guide to departments and faculties to writing a business case for grid collaboration
4 develop a costing template
5 develop a risk assessment framework and guide
6 develop a need-to-know guide for campus leaders
7 identify and acquire skills needed for grid implementation
8 develop and implement service agreements and policies.

References

Ajzen, I. (1991) 'The theory of planned behavior', *Organizational Behavior and Human Decision Process*, Vol. 50, No. 2, pp.179–211.

Alexandru, C. and Jörn, A. (2007) 'A pricing information service for grid computing', *Proceedings of the 5th international Workshop on Middleware for Grid Computing*, *The ACM/IFIP/USENIX 8th International Middleware Conference*, 26–30 November 2007, Newport Beach, California, *MGC '07*, ACM, New York, NY, pp.1–6, DOI=http://doi.acm.org.offcampus.lib.washington.edu/10.1145/1376849.1376853.

Amit, S., Saurabh, K., Jaideep, D. and Vasudeva, V. (2010) 'Towards analyzing data security risks in cloud computing environments', *Proceeding of ICISTM 2010*, CCIS, Springer, Vol. 54, pp.255–265.

Boon, L., David, F. and John, M. (2006) 'Resource discovery services for grid computing training', *International Conference for Web-based Learning*, 19–21 June, Penang, Malaysia, available at http://hdl.handle.net/1842/1535.

Bradley, S. and Hanan, L. (2005) 'Policies, grids and autonomic computing', *Workshop on Design and Evolution of Autonomic Application Software (DEAS 2005)*, pp.1–5.

Choo, F.H, Gay, K.L, Hosseini, H.M. and Teo, C.B. (2007) 'E-learning grid – an online learning network', *Proceedings of the 7th WSEAS International Conference on Distance Learning and Web Engineering*, September 15–17, Beijing, China, pp.310–314.

Christian, M.M.O. (2010) 'The adoption of inter-organizational systems in financial services', *E-Finance Lab Quarterly*, Vol. 3, pp.6–8, available at http://www.efinancelab.de/fileadmin/documents/newsletter/printed/print10-3.pdf.

Contreras, P. and Murtagh, F. (2005) 'AstroGrid as an e-learning environment', *1st International Kaleidoscope Learning Grid SIG, Workshop on Distributed e-Learning Environments*, Vico Equense, Naples, Italy.

Cooper, R.B. and Zmud, R.W. (1990) 'Information technology implementation research: a technological diffusion approach', *Management Science*, Vol. 36, No. 2, pp.123–139.

David, O., Louise, D. and Brian, C. (2010) 'Evaluating trust in grid certificates', *Proceeding of SAC'10*, Sierre, Switzerland, 22–26 March, pp.1449–1453.

Davis, F.D. (1989) 'Perceived usefulness, perceived ease of use, and user acceptance of information technology', *MIS Quarterly*, Vol. 13, No. 3, pp.319–340.

Douglas, T. and Christopher, M. (2007) 'Efficient access to many small files in a file system for grid computing', *Proceeding of IEEE 8th Grid Computing Conference*, pp.243–250.

Earl, J. and John, H. (2004) *Grid Computing for Database-centric Applications*, IDC Research Document No. 31942, published as part of an IDC continuous intelligence service, Vol. 1

Educase and Nacubo (2010) *Shaping the Higher Education Cloud*, May, Educase and Nacubo White Paper.

Elisa, B., Wonjun, L., Anna, C.S. and Bhavani, T. (2008) 'End-to-end accountability in grid computing systems for coalition information sharing', *CSIIRW '08*, 12–14 May, Oak Ridge, Tennessee, USA.

Foster, I. and Kesselman, C. (2004) *The Grid2: Blueprint for a New Computing Infrastructure*, Elsevier, available at http://www.elsevierdirect.com/ISBN/9781558609334/The-Grid-2.

Foster, I., Kesselman, C. and Tuecke, S. (2001) 'The anatomy of the grid, enabling scalable virtual organization', *International Journal on Supercomputer Applications*, Vol. 15, No. 3, pp.200–222.

Gridbriefings (2008) 'Grid computing and standardization: thinking inside the box', *GridTalk*, available at http://www.gridtalk-project.eu (accessed on 20 June 2010).

Heather, S. and Benn, K. (2004) 'Grid computing: the technical, organizational and strategic challenges of the shift to on-demand computing power', *MIT Sloan Management Review*, Vol. 46, No. 1, pp.6–9.

Jin, H. (2004) 'ChinaGrid: making grid computing a reality', *International Conference on Asian Digital Libraries, Lecture Notes in Computer Science, 2004*, pp.13–24.

Joseph, J., Ernest, M. and Fellenstein, C. (2004) 'Evolution of grid computing architecture and grid adoption models', *IBM Systems Journal*, Vol. 43, No. 4, pp.624–645.

Jukniute, A. and Paulikas, G. (2007) 'Sands VO: e-learning system architecture for grid environment', *Information Technology and Control*, Vol. 36, No. 1A, pp.133–138.

Jun, F., Glenn, W. and Marty, H. (2007) 'Resource usage policy expression and enforcement in grid computing', *Proceeding of IEEE 8th Grid Computing Conference*, pp.66–73.

Kentaro, F.B.J., Michael, B. and Nihar, T. (2005) *Introduction to Grid Computing*, Technical Report 1, IBM International Technical Support Organisation.

Kumar, M., Ramu, P., Nava, J., Annie, J., Radhika, K. and Sarat, C.B. (2008) 'Blending grid, ubiquitous computing and web technologies for e-learning (GRUBWEL)', *UbiComp India 2008 Workshop*, September.

Kurta, M. (2010) *On the Road Towards Cloud Computing Services*, Masters thesis of the Erasmus School of Economics, Erasmus University.

Leila, I., Mohamed, A.S., Said, E. and Yacine, A. (2007) 'Semantic grid-based e-learning architecture', *Proceeding of IEEE International Conference on Semantic, Knowledge and Grid (SKG 2007)*, October, Xi'an, Shan Xi, China, pp.511–514, available at http://www.ieeexplore.ieee.org/xpl/freeabs_all.jsp?isnumber=4438493&arnumber=4438607&count=161&index=113 (accessed on 13 June 2010).

Li, Q., Lau, R.W.H., Shih, T.K. and Li, F.W.B. (2008) 'Technology supports for distributed and collaborative learning over the internet', *ACM Trans. Intern. Tech.*, Vol. 8, No. 2, Article 10, pp.10.2–10.24, available at http://demonstration.mine.tku.edu.tw/files/sj05.pdf (accessed on 23 June 2010).

Lim, J.Y. (2010) 'Technology for better business outcomes', March, News Letter of Hewlett-Packard Development Company.

Lingfen, S. and Emmanuel, C.I. (2005) 'The impact of grid on healthcare', *Proceedings of 2nd International Conference on Computational Intelligence in Medicine and Healthcare (CIMED 2005)*, Costa da Caparica, Lisbon, Portugal, available at http://www.tech.plymouth.ac.uk/spmc/people/lfsun/publications/cimed2005-lsun.pdf (accessed on 28 May 2010).

Manvi, S.S. and Birje, M.N. (2010) 'A review on wireless grid computing', *International Journal of Computer and Electrical Engineering*, Vol. 2, No. 3, pp.469–474.

Maozhen, L. and Marios, H. (2008) 'Curriculum development on grid computing', *International Journal of Education and Information Technologies*, Vol. 2, No. 1, pp.71–78.

Marc, E., Jiří, K. and Stefano, A.C. (2005) 'Peer conversations for e-learning in the grid', *First International ELeGI Conference on Advanced Technology for Enhanced Learning 2005*.

McKenna, J. (2006) 'Digital divide narrows according to the McKenna's seventh annual e-readiness rankings', *Economist Intelligence Unit*, available at http://store.eiu.com (accessed on 22 December 2006).

Nabil, S. (2010) 'Cloud computing for education: a new dawn?', *International Journal of Information Management*, Vol. 30, pp.109–116

Omid, K., Jiahua, H., Catherine, O., Allan, S. and Henri, C. (2006) 'Measuring the performance and reliability of production computational grids', *Proceedings of IEEE Grid Computing Conference*, pp.293–300.

Oracle Corporation (2009) *Oracle Grid Computing*, An Oracle White Paper, June.

Paul, P., Felician, A. and Marius, V. (2010) 'Measuring the efficiency of cloud computing for e-learning systems, *WSEAS Transactions on Computers*, Vol. 9, No. 1, pp.42–51.

Pin, H., Lingfen, S. and Emmanuel, I. (2007) *An Approach to Structured Knowledge Representation of Service-oriented Grids*, available at http://www.allhands.org.uk/2007/proceedings/papers/843.pdf (accessed on 5 May 2010).

Rajkumar, B., Yeoa, C.S., Venugopala, S., Broberg, J. and Brandic, I. (2009) 'Cloud computing and emerging IT platforms: vison, hype, and reality for delivering computing as the 5th utility', *Future Generation Computer Systems*, Vol. 25, No. 6, pp.599–616.

Ramkumar, D. (2009) *Cloud Computing: Key Consideration for Adoption*, An Infosys Technology Ltd. White Paper, available at http://www.infosys.com/cloud-computing/white-papers/documents/cloud-computing.pdf (accessed on 15 July 2010).

Rogers, E.M. (1983) *Diffusion of Innovations*, 3rd ed., The Free Press, New York.

Rogers, E.M. (1995) *Diffusion of Innovations*, 4th ed., The Free Press, New York.

Saleh, S.A. (2010) *Regionally Distributed Architecture for Dynamic e-Learning Environment (RDADeLE)*, PhD thesis submitted to Faculty of Technology De Montfort University, Leicester, UK.

Sangroya, A., Kumar, S., Dhok, J. and Varma, V. (2010) 'Towards analysing data security risks in cloud computing environments', *Conference on Information Systems, Technology, and Management*, Bangkok, pp.255–265.

Souvik, R. and Zhao, Z. (2004) 'An efficient anonymity protocol for grid computing', *Proceedings of the Fifth IEEE/ACM International Workshop on Grid Computing (GRID'04)*.

Subhas, C.M. and Arka, M. (2011) 'Identification of a company's suitability for the adoption of cloud computing and modelling its corresponding return on investment', *Elsevier Journal of Mathematical and Computer Modelling (2010)*, Vol. 53, Nos. 3–4, pp.504–521.

Sultan, N. (2010) 'Cloud computing for education: a new dawn?', *International Journal of Information Management*, Vol. 30, No. 2, pp.109–116.

Tan, M. and Teo, T.S.H. (2000) 'Factors influencing the adoption of internet banking', *Journal of the Association for Information Systems*, Vol. 1, No. 5, pp.1–42.

Uzoka, F.M.E. and Nzinge, T (2009) 'Empirical analysis of biometric technology adoption in Botswana', *Journal of Software and Systems*, Vol. 82, No. 9, pp.1550–1564.

Victor, P. and Gottfried, V. (2003) 'Towards e-learning grid: using grid computing in electronic learning', *Proceeding, IEEE Workshop on Knowledge Grid and Grid Intelligence* (in conjunction with *2003 IEEE/WIC International Conference of Web Intelligence/Intelligent Agent Technology*), Saint Mary's University, Halifax, Nova Scotia, Canada, pp.4–15.

Wheeler, B. and Waggener, S. (2009) 'Above campus services: shaping the promise of cloud computing for higher education', *Educase Review*, November–December, Vol. 44, No. 6, pp.52–66

Won, K., Soo, D.K., Eunseok, L. and Sungyoung, L. (2009) 'Adoption issues for cloud computing', *MoMM'2009 – The 7th International Conference on Advances in Mobile Computing and Multimedia*, 14–16 December 2009, Kuala Lumpur, Malaysia.

Yang, C-T. and Ho, H-C. (2005) 'An e-learning platform based on grid architecture', *Journal of Information Science and Engineering*, Vol. 21, pp.911–928.

Zhang, S., Zhang, S., Chen, X. and Huo, X. (2010) 'Cloud computing research and development trend', *Second International Conference on Future Networks*, IEEE Computer Society, pp.93–97.