Critical Factors for the Adoption of Virtualization Software: An Empirical Study

Said Ally
Department of ICT and Mathematics, The Open University of Tanzania, Dar es Salaam, Tanzania
said.ally@out.ac.tz

Received: 05-FEB-2023; Reviewed: 16-JUN-2023; Accepted: 05-JUL-2023
http://doi.org/10.46792/fuoyejet.v8i3.1002

ORIGINAL RESEARCH

Abstract- The growth of virtualization technologies has allowed cloud adopters to make better use of computing resources. Despite its rapid expansion, adopters are having difficulty locating an appropriate virtualization solution and realizing the desired benefits. Six adoption factors were found to be the essential aspects of virtualization software for a seamless transition from physical to virtual computing after 43 tools and seven constructs were extracted using technology diffusion techniques. Based on the effect level, they are the software features, innovation risk, environmental factor, relative advantage, perceived usefulness, and social system. For public entities, the transition is specifically driven by ICT policies, regulations, and costs, whereas private sectors rely on market trends, the business status quo, and expert ranking. Adopters can utilize the study's findings as a strategic signal for a risk-free switch from physical to virtual computing, while vendors can leverage the design attributes to enhance software functionality.

Keywords- Virtualization software, Cloud computing, Hypervisor, Server virtualization, Virtual machine.

1 Introduction

Investment in information technology is undergoing a paradigm shift from physical to virtual computing.

Virtualizing server resources is one of the fundamental techniques used in cloud computing and contemporary data centres. The technique has already given its users tremendous economic potential on a global scale, and it is currently one of the fastest-growing ICT fields (Li & He, 2021). For instance, network virtualization already holds a 92% market share across all data centres (Cisco, 2016; Spiceworks, 2016; Crockett, 2022), and according to Market Data Forecast's 2022 forecast, it will reach $51 billion in 2027 at a compound annual growth rate of 23%. The vast economic and technological benefits that adopters gain include increased system security due to the isolation provided by virtual machines (Pearce et al., 2013; Obasuyi & Sari, 2015) and a significant cost reduction that is largely fuelled by making better use of computing resources including hardware, software, personnel, energy savings, and space. Given that power consumption is a major barrier in developing countries, some telecommunications companies have been able to reduce production costs by replacing many outdated servers with virtual machines (Thomas and Belle, 2017), a vital computing approach for a greener world (Addo et al., 2019), since hardware resources are highly exploited through the creation of energy-efficient virtual servers. If the business does not virtualize its computing infrastructure, the cost associated with information technology might potentially double (Uhlig *et al*., 2005; Infographic, 2014).

*Corresponding Author

Section B- ELECTRICAL/COMPUTER ENGINEERING & RELATED SCIENCES
Can be cited as:
Ally S., (2023). Critical Factors for the Adoption of Virtualization Software: An Empirical Study, FUOYE Journal of Engineering and Technology (FUOYEJET), 8(3), 273-277. http://doi.org/10.46792/fuoyejet.v8i3.1002

The process of virtualizing server resources is completed by using virtualization software, for establishing a full-fledged virtual execution environment, which is a container or virtual machine, each with its own guest operating system and the allocated virtual resources for processor (CPU), memory (RAM), and storage (HDD). Being a critical computing apparatus, the choice of virtualization software has piqued the interest of adopters, especially in terms of its compatibility with operating systems for host and guest machines, the size of virtual resources, and the mode of resource usage between static and dynamic allocation. For that reason, virtualization software is regarded as a decisive factor that determines whether a virtualization project succeeds or fails.

The proliferation of an interconnected global digital economy and the existence of a variety of virtualization software on the international market have made it extremely difficult for adopters to choose which software to adopt and use. As a result of insufficient software deployment and an ad hoc adoption procedure, adopters rarely reap the promised economic benefits. Although developing countries can benefit from virtualization (Kizza, 2008), the spread of technology has never been straightforward (Sabi et al., 2016). One of the most complex challenges in the study of emerging technologies, like with any other technology adoption, has been figuring out why adopters embrace or reject a particular technology (Rodriguez, 2012).

The lack of knowledge and awareness in the virtualization process (Njue, 2015; Letlonkane et al., 2016) and security uncertainties (Ally & Jiwaji, 2022) are the major barriers to the institution's benefits from virtualization. Due to the fact that a full-fledged virtual execution environment is simply a computer file, adopters run a high risk of web attack from multiple threat sources such as the network, other virtual machines, the hypervisor, and personnel. Because the criteria for selecting an appropriate platform are still unclear, adopters have been quite concerned about choosing virtualization software due to all of these threat sources. For instance, some of the prominent issues that prevent adopters from selecting the appropriate virtualization software include:

- choice between hypervisor virtualization or containerization,
- use of hypervisor type 1, type 2, or hybrid mode,
- choosing between open source and proprietary soft ware licenses,
- processor compatibility between Intel VT-x and AMD-V,
- operating system support for both host and guest machines,
- maximum number of supported virtual machines,
- compute (virtual CPU), storage (virtual HDD), memory (virtual RAM), and network (virtual NIC) capabilities for resource allocation capabilities, and the
- infrastructure configuration between homogeneous and heterogeneous

With all these concerns, the adoption process has remained ad hoc, and adopters' choice of particular virtualization software has never really been an institutional concern. Prior research on crucial factors impacting virtualization software adoption has been limited. Thus, the goal of this research is to determine the key factors that influence adopters' decisions to choose a specific type of virtualization software. Understanding these constructs and their level of influence is critical for a successful virtualization project. Given that the success or failure of a project is totally dependent on the choice of virtualization software, this study gives critical feedback to software manufacturers so that they may improve their products and to adopters so that they can make an informed decision when looking for an appropriate virtualization platform.

2 Material and Methods

2.1 Determination of Adoption Constructs

The study is based on the deductive approach, where a thorough review of four well-known adoption models and theories, including the theory of reasoned action (Fishbein & Ajzen, 1975), the theory of planned behaviour (Ajzen, 1985, 1991), the technology acceptance model (Davis, 1989), and the theory of innovation diffusion (Rogers, 2003), was used to derive the adoption constructs. The chosen models play a significant role in the study of innovation diffusion and have the ability to connect attitudes and behaviours within human action (Chuttur, 2009). The TAM model is regarded as the best theory that can model how users accept and use technology, according to Davis (1989), and which fits specifically in information technology (Sabi *et al*., 2016), despite being criticized due to the limitation of PE as a determinant of attitude and intention to use (Hu et al., 1999) and its usage limitation, which accounts for only 40% of a technological system's use (Legris et al., 2003). On the other hand, the innovation diffusion theory examines how, why, and how quickly new technology is adopted (Rogers, 2003).

Although the applied models can be used to examine adoption at various levels, including the macro view at the national level (Press et al., 2002), the organizational level (Plouffe et al., 2001), and the individual level (Mathieson, 1991), for the purposes of this study, all four models have been integrated to provide a comprehensive set of adoption constructs that are pertinent to virtualization software. Thus, a total of seven adoption constructs, including perceived usefulness (PU), perceived ease of use (PE), social system (SS), environmental factors (EV), relative advantage (RA), innovation risks (IR), and software features (SF), have been identified and are being used as key determinants for the software selection process. The perceived usefulness (PU) and perceived ease of use (PE) are still considered the most standard instruments with significant values for assessing technology adoption (Segars and Grover, 1998) despite a progressive expansion of TAM, TAM 2, TAM 3, and the Unified Theory of Acceptance and Use of Technology (UTAUT) from time to time (Venkatesh & Davis, 1996). The percentage contribution of each adoption model for the proposed adoption constructs is presented in Table 1.

Table 1. Mapping of adoption constructs

Adoption Model	Constructs		Construct Mapped
	N	%	
Innovation Diffusion Theory (IDT)	5	71.4	PE, PU, RA, IR, SF
Theory of Planned Behaviour (TPB)	5	71.4	SS, EV, RA, IR, SF
Technology Acceptance Model (TAM)	4	57.1	PE, PU, RA, SF
Theory of Reasoned Action (TRA)	1	14.3	SS

Table 1 shows that the IDT, TPB, and TAM models were used to extract the majority of the adoption constructs. The IDT and TPB theories were mapped into five constructs, accounting for 71.4%, while the TAM model was mapped into four constructs, accounting for 57.1%. Each adoption component was typically mapped against two models.

2.2 Assessment Focus

Each selected adoption construct focuses on specific attributes that guide the whole process of selecting and deploying virtualization software. Major focus areas include:

- Perceived Ease of Use (Simplicity; Relieve administrators of mental efforts),
- Perceived Usefulness (Software Performance; System Effectiveness),
- Social System Factors (Presence and Enforcement of ICT Policies; Technology Market Trends; Virtualization Usage Experience; Expert Recommendations; Acquisition Costs; Knowledge Coverage in Academic Curricula),
- Environmental Factors (Technology compatibility; Software and implementation methods; Number of

http://doi.org/10.46792/fuoyejet.v8i3.1002 journal.engineering.fuoye.edu.ng/

users; Infrastructure challenges (space, power, performance, storage/consolidation, control; Server count),

- Relative Advantage (Software support and maintenance; System reliability; Technology dynamics),
- Innovation Risks (Software capability as IPS and IDS in responding to web attacks; Uncertainty of technological innovation; Upgrading and patching process; Collaboration with technology vendors),
- Software Features (Number of virtual machines; Software maturity; License type; Live migrations; failover; Load balancing; Number of supported guest OS; Size of virtual resources (vCPUs, vHDDs, vRAMs); Application programming interface (API) style; Hypervisor GUI; Flexibility as a heterogeneous platform; Virtual machine isolation level).

2.3 Population Sampling

A sampling frame based on a purposive non-probabilistic approach (Battaglia, 2011) was confined to 24 organizations (15 public and 9 private) registered in Tanzania that have already virtualized their servers. Respondents in each firm were server administrators, who are in charge of setting up and managing virtual machines and who play a significant role in the adoption and selection of virtualization software. The average years of experience in using virtual systems are 7 years for public entities and 9 years for private entities.

Over 97% of respondents have a BSc or MSc in computer science degree, and three-quarters of them are men. Data was collected over a five-month period, from May to September 2022. The technology adopter is a basic unit of analysis, and for the sake of this research, the adopter is defined as both an individual and a virtualized company (Meyer, 2004).

2.4 Reliability Test

To test the validity of the seven adoption constructs, a document analysis (Kumar, 2011) and a quantitative approach were used for data collection. A total of 43 assessment items were set in a self-administered semi-structured questionnaire based on a 5-point Likert scale rating from 1 for strongly disagree to 5 for strongly agree. Out of 30 distributed questionnaires, 29 were useful to analyse with a response rate of 96.7%, thus making up a total of 1,247 responses. The consistency and reliability test of a questionnaire as a valid research instrument was performed using a Cronbach alpha, which recorded a general α-value of 0.803 for all 43 items. However, for each adoption construct, the number of responses varied depending on the measurement instrument. Table 2 shows the number of responses for each construct for 29 respondents.

Table 2. Responses based on adoption constructs

Adoption construct	Frequency		α–value
	Items	*Responses*	
PE	9	261	0.75
PU	7	203	0.96
SS	7	203	0.73
EV	4	116	0.71
RA	4	116	0.85
IR	6	174	0.79
SF	6	174	0.88
Total	**43**	**1247**	**0.803**

All values fall within an acceptable range for internal consistency (0.9 > α ≥ 0.7), with a minimum value of 0.71 for environmental construct and a maximum value of 0.96 for perceived usefulness. This implies that the reliability test is successful because the threshold for the composite reliability is α ≥ 0.7 (Hair et al., 2010).

3 Results

The results suggest that over three-quarters (81%) of the assessment items are valid indicators and qualify to be considered adoption factors. Table 3 shows the number and percentage of valid indicators for each adoption construct, acceptance level, and rank.

Table 3. Valid adoption constructs and ranking

Type	Median	Acceptance level		Rank
		N	%	
SF (6)	4 & 5	6	100	1
IR (6)	4	6	100	2
RA (4)	4	4	100	4
EV (4)	4 & 5	4	100	3
SS (7)	4	5	71.4	6
PU (7)	4	6	85.7	5
PE (9)	4	4	44.4	7
43	**35**	**35**	**81.4**	

Four adoption constructs, including software features, innovation risks, environmental factors, and relative advantages, have an acceptance rate of 100% as critical factors and are crucial in determining whether a certain virtualization software will be adopted based on the criteria set by adopters. The median value of each of these constructs is 4, indicating that they all have an equal influence on the selection process.

The selection process of the virtualization software is also influenced by perceived usefulness and social system factors. For perceived usefulness, adopters focus on virtual machine management, support of critical functionalities in server management, usability properties, and multiprocessing. For the social system factor, the adoption process is influenced by enforcement of ICT policy, market trends, experience from other virtualized companies, software ranking and cost.

http://doi.org/10.46792/fuoyejet.v8i3.1002 journal.engineering.fuoye.edu.ng/

Another interesting result of this study is the acceptance rate of 44% for the perceived ease of use. This implies that the construct is not a dominant factor in the software choice. This conforms to the original TAM model, in which the perceived ease of use is not hypothesized to directly affect adoption intention. Thus, the identified critical adoption factors in order of their impact level on the choice of virtualization software are: software features = 1, innovation risk (security) = 2, environmental factors = 3, relative advantages = 4, perceived usefulness = 5, and social system = 6. Given that all these constructs have scored more than 70%, it is interpreted that adopters must consider all six factors in the adoption process, as clearly indicated in Figure 1.

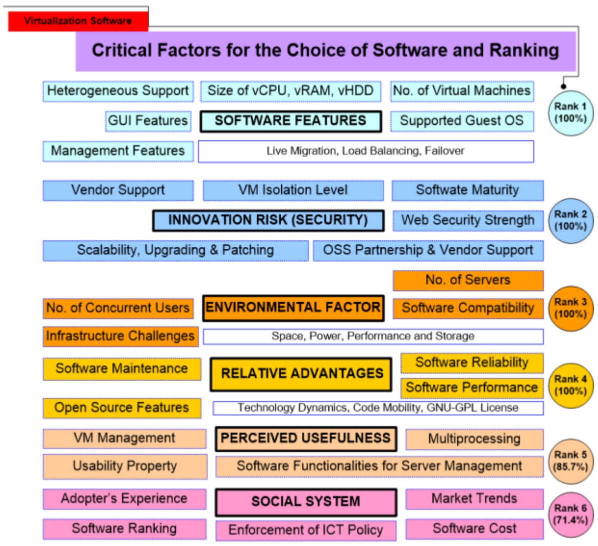

Fig 1: Critical factors for the choice of virtualization software and ranking

As clearly indicated in Figure 1, in the process of virtualizing servers, the following are the important attributes in each adoption factor that must be considered by the adopters when selecting virtualization software:

- Software Features (Rank 1-100%): number of virtual machines, supported guest OS, size of allocated virtual resources (vCPU, vRAM, and vHDD), presence of GUI features, support for heterogeneous infrastructure, and management features (live migration, load balancing, and failover).
- Innovation Risk (Rank 2-100%): strengths of the hypervisor's web security, isolation between virtual machines, open-source partnership and vendor support, scalability, upgrading and patching processes, and software maturity.
- Environmental Factor (Rank 3-100%): hypervisor compatibility, supported number of concurrent users, supported number of servers and virtual machines, and infrastructure challenges (space, power, performance, and storage).
- Relative Advantage (Rank 4-100%): hypervisor support and maintenance, performance, reliability, and open-source properties (technology dynamicity, mobility, and GNU-GPL license).
- Perceived Usefulness (Rank 5-85.7%): virtual machine management, usability, multiprocessing, and software functionality for server management.
- Social System (Rank 6-71.4%): adopter's experience, market trends, software ranking, enforcement of ICT policy, and software cost.

4 Discussion

The fact that virtualization is heavily carried out on the server side can be a reason why the construct's perceived ease of use did not significantly affect the adoption process. This implies that adopters are unsure about software failures, the recovery process, and unexpected behaviour that would force them to regularly consult the user manual. This is in perfect agreement with the original TAM model, which did not predict that adoption intention would be directly influenced by perceived ease of use. For adopters to benefit from virtualizing their computing resources, six factors must be considered throughout the adoption process.

Based on how much they affect the virtualization adoption process, the following were identified as adoption factors in the order that defines their effect level: Software features = 1, Innovation risk (security) = 2, Environmental factor = 3, Relative advantages = 4, Perceived usefulness = 5, and Social system = 6. According to Table 3, each of these factors had a score of at least 70%. The first four adoption factors are thought to have a significant influence on the decision process, all of which are universally acknowledged.

A comparative analysis between the public and private sectors has shown that a social system factor is perceived differently by adopters because public adopters are primarily driven by social influence aspects pertaining to policies, government directives, and cost difficulties, while private entities are mostly influenced by market trends, the status quo of business competitors, and expert ranking. For this reason, regardless of the category, adopters should be able to harmonize and balance the driving adoption factors to maximize the benefits of virtualizing their computing resources. This will prevent them from feeling psychologically terrified of lagging behind their commercial rivals if they do not use a particular virtualization software.

Given that innovation risk is the second most influential adoption factor with a 100% acceptance rate, it is obvious that adopters are more concerned with security attributes. Some of the common security attributes include software strength in responding to web attacks, risks due to open-source innovation, software scalability and maturity, upgrading and patching processes, support and technology partnerships, and a degree of virtual machine isolation for guest-to-guest and host-to-guest attacks. This result concurs with Ahmed and Litchfield (2018), who advocate increased security concerns among adopters of virtual computing.

http://doi.org/10.46792/fuoyejet.v8i3.1002 journal.engineering.fuoye.edu.ng/

5 Conclusion

In virtual computing, technology users are eager to understand the critical factors influencing the choice of specific virtualization software. Due to the fact that there are a number of software options, the results presented are especially beneficial for adopters to make informed decisions on the choice of virtualization software to attain maximum benefits from virtualizing their computing resources. While relative advantages and environmental considerations are key issues in the virtualization process, security and software characteristics remain significant factors in the decision-making process. This is explained by the widespread use of various virtualization tools and the dangers involved in using them in virtual environments and cloud computing. The study's findings might be used as a strategic indicator by adopters to ensure a smooth and secure transition from physical to virtual computing.

References

Addo, P. C., Akabua, C., & Akpatsa, S. K. (2019). Leveraging Network Virtualization for Safer and Greener Communication in Africa. In 2019 IEEE AFRICON (pp. 1-9). IEEE.

Ahmed, M., & Litchfield, A. T. (2018). Taxonomy for identification of security issues in cloud computing environments. Journal of Computer Information Systems, 58(1), 79-88.

Ajzen I., (1991). The theory of planned behavior, Organizational Behavior and Human Decision Processes, 50 (2), 179-211

Ajzen, I. (1985). From intentions to actions: A theory of planned behavior, In J. Kuhl, & J. Beckmann (Eds.), Action control: From cognition to behavior. New York: Springer-Verlag

Ally, S., & Jiwaji, N. (2022). Common inhibiting factors for technology shifting from physical to virtual computing. Ethiopian Journal of Science and Technology, 15(2), 125-139.

Battaglia, Michael P., (2011). Nonprobability sampling, Encyclopedia of Survey Research Methods, 2008, SAGE Publications, 8 Nov 2011, pp. 523 – 526

Chuttur M.Y., (2009). Overview of the technology acceptance model: Origins, Developments and Future Directions, Indiana University, USA, Sprouts: Working Papers on Information Systems, 9(37). http://sprouts.aisnet.org/9-37

Cisco, (2016). Cisco global cloud index: Forecast and methodology, 2015–2020., White Paper Cisco Public", C11-738085-00 11/16, http://www.cisco.com/c/dam/en/us/solutions/collateral/service-provider/global-cloud-index-gci/white-paper-c11-738085.pdf. Date Accessed: July 11, 2017

Crockett E. (2022). The Network Virtualization Market in 2022. Enterprise storage forum. Website: https://www.enterprisestorageforum.com/networking/network-virtualization-market/. Date accessed: 05-07-2022

Davis, F., (1989). Perceived usefulness, perceived ease of use and user acceptance of information technology, MIS Quarterly: Management Information Systems, Volume 13, pages 319-339. URL: http://business.clemson.edu/ise/html/perceived_usefulness__perceive.html, Date Accessed: November 10, 2016.

Fishbein, M. & Ajzen, I., (1975). Relief, attitude, intention and behaviour: An introduction to theory and research. Addison – Wesley Pub. Co: Reading Mass; Don Mills, Ontario

Hair, J., Black, W., Babin, B., & Anderson R., (2010). "Multivariate data analysis, 7th edition, Upper Saddle River, NJ., USA: Prentice – Hall, Inc

Hu, P. J., Chau, P. Y. K., & Sheng, O. R. L. (1999). Examining the technology acceptance model using physician acceptance of telemedicine technology, Journal of Management Information Systems, 16 (2): 91–112

Infographic, (2014). Top 5 reasons why you can't afford not to virtualize. Infographic Whitepaper on VMware https://www.vmware.com/content/dam/digitalmarketing/vmware/en/pdf/infographic/vmw-top5-reasons-infographic.pdf. Date Accessed: July 11, 2017

Kizza, J. M. (2008). Africa Can Greatly Benefit from Virtualization Technology–Part, International Journal of Computing and ICT Research, Vol. 6, Issue 1, June 2012

Kumar R., (2011). Research methodology. A step-by-step guide for beginners. 3rd edition, SAGE Publications, ISBN: 978-1-84920-300- New Delhi, India

Legris, P., Ingham, J., & Collerette, P., (2003). Why do people use information technology? A critical review of the technology acceptance model. Information & Management, 40 (3): 191–204.

Letlonkane, L., Bukohwo, M. E., & Molehabangwe, G. (2016, September). Cloud Storage Usage by Students of the Northwest University South Africa. In 10th European Conference on Information Systems Management: ECISM 2016 (p. 124). Academic Conferences and publishing limited.

Li, Y., & He, Y. (2021, August). Research on Computer Application Technology Based on Big Data Environment. In Journal of Physics: Conference Series (Vol. 1992, No. 2, p. 022127). IOP Publishing.

Market Data Forecast, (2022). Network function virtualization. Website: https://www.marketdataforecast.com/market-reports/network-function-virtualization. Date accessed: 05-07-2022.

Mathieson K., (1991). Predicting user intention: Comparing the technology acceptance model with the theory of planned behavior, Information Systems Research, 2, 3, 173 – 191

Meyer, G. (2004). Diffusion methodology: Time to innovate? Journal of Health Communication: International Perspectives. 9(S1): 61.

Njue, M. K. (2015). The Effect of ICT Industry Standards on the Success of Server Virtualization-A Case Study of Africa Nazarene University (Doctoral dissertation, Africa Nazarene University).

Obasuyi, G.C. & Sari, A., (2015). Security challenges of virtualization hypervisors in virtualized hardware environment. Int. J. Communications, Network and System Sciences, 8, 260-273. http://dx.doi.org/10.4236/ijcns.2015.87026

Pearce, M., Zeadally, S., & Hunt, R. (2013). Virtualization: issues, security threats, and solutions. ACM Computing Surveys (CSUR), 45(2), 17. 39 pages. DOI = 10.1145/2431211.2431216 http://doi.acm.org/10.1145/2431211.2431216

Plouffe, C. R., Hulland, J. S., & Vandenbosch, M. (2001). Richness versus parsimony in modeling technology adoption decisions—understanding merchant adoption of a smart card-based payment system, Information Systems Research, 12(2), 208-222

Press, L., Foster, W., Wolcott, P., & McHenry, W. (2002). The internet in India and China. First Monday, 7(10).

Rodriguez, L. F., (2012). The technology acceptance model (TAM) as a viable model to determine the acceptance of e-learning technologies in higher education institutions (HEI's)", http://works.bepress.com/luis_rodriguez/8

Rogers, E., (2003). Diffusion of innovations. 5th Edition, Simon and Schuster. ISBN 978-0-7432-5823-4.

Sabi H. M., Uzoka F. E., Langmia K., Njeh F. N., (2016). Conceptualizing a model for adoption of cloud computing in education. International Journal of Information Management, 36 (2016), 183-191

Segars, A. H. & Grover, V. (1998). Strategic information systems planning success: An investigation of the construct and its measurement. MIS Quarterly, 22(2), 139-163.

Spiceworks, (2016). Server virtualization and OS trends. Spiceworks State of IT Report – Networking Article. https://community.spiceworks.com/networking/articles/2462-server-virtualization-and-os-trends, Date Accessed: July 11, 2017

Thomas, M., & Van Belle, J. P. (2017). Virtualization Footprint: Why Re-Invest? Journal of Information Technology Education: Discussion Cases, 6(1).

Uhlig, R., Neiger, G., Rodgers, D., Santoni, A.L., Martins, F.C.M., Anderson, A.V., (2005). Intel virtualization technology. Computer, 38, 48-56. http://dx.doi.org/10.1109/mc.2005.163

Venkatesh, V. & Davis, F.D., (1996). A model of the antecedents of perceived ease of use: development and test., Decision Sciences. 27 (3): 451–481.

http://doi.org/10.46792/fuoyejet.v8i3.1002 journal.engineering.fuoye.edu.ng/