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Belachew U. Regane
Addis Ababa University, belachew.regane@aau.edu.et

Sisay Yemata
Addis Ababa University, sisay.yemata@aau.edu.et

Kassaye Tilahun
Debre Birhan University, ktilahun92@gmail.com

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Software Engineering Methods for the Internet of Things: A Comparative Review

Belachew Regane[1], Sisay Yemata[1], Kassaye Tilahun[2]

[1] Department of computer science, Software Engineering Track, Addis Ababa University, Addis Ababa, Ethiopia

[2] Department of Information Technology, Debre Birhan University, Debre Birhan, Ethiopia

belachew.regane@aau.edu.et

Sisay.yemata@aau.edu.et

ktilahun92@gmail.com

Abstract

Accessing different physical objects at any time from anywhere through wireless network heavily impacts the living style of societies worldwide nowadays. Thus, the Internet of Things has now become a hot emerging paradigm in computing environments. Issues like interoperability, software reusability, and platform independence of those physical objects are considered the main current challenges. This raises the need for appropriate software engineering approaches to develop effective and efficient IoT applications software. This paper studies the state of the art of design and development methodologies for IoT software. The aim is to study how proposed approaches have been solved issues of interoperability, reusability, and independence of the platform. A comparative study is presented for the different software engineering methods used for the Internet of Things. Finally, the key research gaps and open issues are highlighted as future directions.

Keywords: Internet of Things, Software engineering methods, Interoperability. Reusability, Platform

independence

I. INTRODUCTION

The number of Internet-connected devices is increasing at a rapid rate. These devices include personal computers, laptops, tablets, smartphones, personal digital assistants (PDAs), and other handheld embedded devices. These physical objects are equipped with Radio-Frequency IDentification (RFID) tags or other identification barcodes that can be sensed by the smart sensor devices (Khan et al., 2012; Hasibur et al., 2017).

Objects in the Internet of Things (IoT) embed intelligence to communicate, exchange information, make decisions, invoke actions, and provide amazing services. Currently, IoT has become popular in academia, industry as well as in governmental organizations. So, it has the potential to bring significant personal, professional, and economic benefits (Khan et al., 2012; Baiyere et al., 2020).

According to Luigi et al. (2010), IoT applications can be categorized into: (i) Transportation and logistics domain, (ii) Healthcare domain, (iii) Smart environment domain, and (iv) Personal and social domain.

Software developed for different infrastructures has been characterized by important activities such as planning, designing, implementation, and development. Traditional application development has always followed a monolithic approach of dividing functionalities into methods and classes. But this is inside the same single unit which is deployed as a process (Mayank 2016). The reliance of modern society's on fragile software has resulted in the increased interest in software engineering (Colin et al., 2017). Without software engineering, it is difficult to think about smart environments like the internet of things. Today, as approaches, software engineering has advanced methods to solve problems in the domain of IoT.

Nowadays, current challenges in IoT are interoperability, software reusability, and platform independence of physical objects. These challenges result in inefficient communications and data transmissions between smart objects. To solve these problems, some solutions have been proposed in the domain of Software Engineering from a different perspective. These include the Component-based Software engineering approach, Object-oriented software engineering approach, Service-Oriented software engineering approach, and Intelligence-based software engineering approach. These proposed solutions have been enhanced the design and development of the Internet of Things. However, some questions are not answered yet. These questions are 1. Which software engineering method(s) do mainly achieve the design and development of IoT software? 2. How do those proposed approaches have been solved issues of interoperability, reusability, and independence of the platform? Therefore, the concern of this study is to answer these research questions. To conduct the research study, the researchers used a comparative research study approach. The researchers follow descriptive comparison based on aspect/view of cases like interoperability, software reusability, and platform independence. This is to investigate the appropriateness of the approaches to develop IoT software that is evolved through time. According to Shahrokh, and Miri (2019) "A comparative study is a kind of method that analyzes phenomena and then put them together to find the points of differentiation and similarity".

The remainder of this paper is organized as follows. Section II introduces about one of the proposed solutions which is a component-based software engineering approach in developing IoT applications software. On this basis, Section III discusses the object-oriented software engineering approach. Section IV discusses the service-oriented software engineering approach which is another aspect of software engineering methods for IoT software design and development. In section V intelligence-based software engineering approach which is one of the proposed solutions is discussed. In section VI some discussions and open issues central to the engineering of IoT software have been discussed and finally, section VII concludes.

II. Component-based Software Engineering Approach

The architectures of component-based software are flexible concerning extensibility and modifiability. Features of component-based software architectures make tasks easy in developing, deployment and management of systems (Barbora et al., 2014; Miroslav and Katarína, 2017).

To simplify and accelerate future development and deployment of IoT applications, generic component-based architecture is proposed as a solution. The architecture follows principles of component-based design of software systems and reusability of components. The architecture can be used to connect different devices for different applications like electrical and electro-mechanical devices (Miroslav and Katarína, 2017; Roy et al., 2017).

On this basis, component-based software can solve problems that arise due to reusability as new devices or objects connected to IoT systems. However, interoperability and platform independence are issues not yet addressed and expected to be researched.

III. Object-Oriented Software Engineering Approach

Distributed object technology is a new computing paradigm. This technology allows objects to be distributed across a heterogeneous network. This enables each of the components to interoperate with each other. Reusability is another important benefit of object-oriented software in this area (Hyoung et al., 1997).

An object-oriented model is proposed to avoid wasting time while searching and downloading. This is to connect smart objects to enable them communicating with each other efficiently. The model can be used to define a set of standard interfaces suitable for every smart object. It is a generic model that can able to describe any kind of smart object. It is a generic and adaptive model that provides an automatic adaptation while moving from one smart space to another environment. Verification of the model is done using two smart spaces (Luca et al., 2017).

The studies addressed challenges concerning interoperability and reusability even if sufficient research is not conducted in the area. Challenges related to the independence of the platform are still not addressed and open.

IV. Service-Oriented Software Engineering Approach

In service-oriented computing (SOC), services are basic elements to develop service-oriented software. As discussed in Selo (2013) and Nik, et al. (2018), service-oriented concepts can be applied in software architecture to analyze, architect, design, implement, test, evaluate, deliver, and maintain computer-based systems. Nowadays, SOC has been applied to many areas. Internet of Things (IoT) is one of the areas.

Giancarlo et al. (2017) discussed future challenges of IoT systems in terms of interoperability. That means interoperability in terms of devices, networking, middleware, application services, data, and semantics. It is Arrowhead Framework, based on a Service-Oriented Architecture. Specifically, it aims to provide a kind of support in the interconnecting and cooperating system of systems in IoT. This is to support how to design, develop, deploy and operate efficiently. Currently, it has been in use at 20 different installations in domains of home and industrial automation, production, virtual markets of energy, and electrical vehicle infrastructures to evaluate its result.

Zou and Quan propose a new service-oriented model with Open Grid Services Architecture (OGSA) for agricultural IoT. Since attributes of agricultural things are heterogeneous by their nature, the traditional IoT model cannot express its complexity and diversity. This service-oriented grid-based method is considered to manage and organize agricultural resources (Yiqin et al., 2017).

Specific to IoT, in Nik, et al. (2018) a service-oriented wireless sensor networks (WSNs) framework that is used to work collectively is reviewed. The objective is to achieve complex applications with the wide adoption of the Internet of Things. Besides this, heterogeneity issues of smart things are addressed. Accordingly, WSN services composition is reduced to a multi-objective and multi-constrained optimization problem, where the particle swarm optimization (PSO) algorithm and genetic algorithm (GA) are adapted to resolve this problem. The outputs of the experiment result in the outperformance of PSO and GA in finding approximately optimal WSN services compositions.

To manage the complexity of software systems and their development in IoT, Abstraction Modelling and Generate (AMG) method is proposed as a solution in Selo (2013). It is a model-driven development approach for the development of software applications in the IoT. It focuses on service composition at design time, but the abstraction step in the AMG can be extended to support run-time compositions. It is also a service-oriented system with Service-Oriented Architectures (SOA). Finally, the method has been prototyped and tested with use cases.

In designing and developing IoT software, service-oriented computing is one of the approaches that make tasks easy. Thus, studies show that to understand the problems and to solve complex real-world

challenges, its contribution is valuable. Interoperability, reusability, and platform independence issues in IoT are addressed to make significant progress in the area.

V. Intelligence-based Software Engineering Approach

Intelligence-based software is self-adaptive so that able to learn from their preferences or their behavior. Unstructured data is used to mine knowledge. Genetic algorithms, fuzzy logic, or neural networks are techniques used in artificial intelligence for controlling and managing intelligent systems (Hyoung et al., 1997).

To enhance the performance of intelligent manufacturing systems, open agent architecture (OAA) is used. OAA is used for the integration of heterogeneous software agents in a distributed environments. This enables agents to interoperate and communicate efficiently with each other. Here, issues of standardization of distributed object brokers and intelligent agents are also discussed (Hyoung et al., 1997; Xue-Yong et al., 2017; Munindar et al. 2017).

In Ali, et al. (2016), the semantic model for smart object description and users request resolution is proposed as a solution. The purpose is to satisfy users with efficient sharing of data, exchanging of services, and cooperation. It uses ontological techniques which are combined with description logic. Reasoning over service data and semantic interoperability among devices are issues considered in the model. The model comprises device description and service description. To verify the effectiveness and usability of the proposed model, a case study is used for smart environment monitoring. Thus, functional requirements are resolved using description logic. Non-functional requirements are evaluated according to the provided quality of service levels by the available services.

To have efficient data management in the IoT domain, a multi-modal context-aware reasoner that provides knowledge at the edge for each IoT application is proposed as a solution in Hasibur, et al. (2017). Using rules-based and Bayesian reasoning techniques, it has been verified in SmartHome, SmartGardening, and SmartHealth applications. The results suggest that the proposed solution can react to the context and provides knowledge at the edge for each IoT application.

In Wen, and Sami (2017), a two-step framework to first design system architecture and then to determine selection criteria for each component is proposed. This is to enable multiple hardware and software interoperable effectively to be used for the monitoring manufacturing environment. In the first step, the construction of Wireless Sensor Network (WSN) architecture which is integrated with IoT is developed. This is to monitor the manufacturing environment. In the second step, the guideline is developed to select a product for each layer. Using a case study for temperature monitoring, the office is tested. Based on the successful result, it is used for monitoring the temperature of a pharmaceutical warehouse.

Intelligence-based software engineering is one of the main approaches currently proposed as a solution to overcome challenges raised in IoT system design and development. So, issues of interoperability, software reusability, and platform independence are addressed in the studies through this engineering method.

VI. Discussions and Open Issues

After the advent of IoT, in the last few years, the living style of people worldwide has been changed. People are living and working in smart cities, and smart environments. IoT enables these people to be benefited from enormous economic benefits generated due to the advancement of IoT. However, IoT faces challenges like interoperability, software reusability, and platform independence which makes deployment of IoT complex. Early focuses of IoT were mostly on the design and development of network connectivity and communication of objects. Studies indicate that little attention has been given to software engineering methods to solve those challenges in the area (Khan et al., 2012; Shim et al., 2020).

As discussed by Giuliano et al. (2016) and Mazen et al. (2017), software engineering methods help to develop sound architectures for addressing and integrating diverse applications software of IoT. This software has to deal with challenges in IoT like interoperability, reusability, and platform independence.

To overcome those challenges, multiple solutions have been proposed. Some of the proposals suggest a component-based approach as a solution. Others suggest the service-oriented approach. The object-oriented approach is also another proposal considered as a solution. The artificial intelligence-based approach is another proposal that considers autonomous software agents. However, issues about interoperability, reusability, and platform independence are not addressed in the same ways in those proposals (Franco, 2016.).

In this paper, comparative studies have been conducted based on the approaches' architectures, models, frameworks, and technologies used in the proposals and paradigms followed. This is performed by categorizing approaches into similar classes. The aim is to study how the proposed approaches have been solved issues of interoperability, reusability, and independence of the platform.

Component-based software designed and developed to be reused by different systems. In terms of interoperability, it needs middleware that supports the communications of objects. This is still a challenge since it hinders the uptake of component-based software even if the standard is set. Issue of platform independence in component-based software engineering approach is still open since it uses a shared platform. In the object-oriented software engineering approach, the studies show that issues of interoperability and software reusability are addressed even if nothing is said about the independence of platforms. In the case of the service-oriented software engineering approach and the intelligence-based software engineering approach, the studies show that three of the issues are addressed. That is the result of their architectural design and development.

Based on the aforementioned concern, interoperability is given high attention compared to others issues since objects should be able to communicate with each other efficiently in IoT. With these considerations, the studies on proposed solutions indicate that intelligence-based software engineering approaches have been seen as generic software engineering methods for IoT. The basic reason is the open architecture it has been using which can support interoperability among agents created in different programming languages and interfaces (Hyoung et al., 1997; Franco, 2016.).

Recently, a little deal of effort has been devoted to software engineering methods to come up with breakthrough solutions in IoT. However, "Which software engineering method(s) do mainly achieve design and development of IoT software?" is still a question that needs answers. The answers will help to make tasks easy to overcome challenges in designing and developing IoT software. Specifically, component-based and object-oriented software engineering approaches are open to being investigated further as future work to answer the question.

VII.   Conclusion

IoT paradigm has been enabling communications with and among smart objects. This has been leading to the vision of any time, anywhere, any media, anything communications. Studies have been conducted in the design and development of IoT applications and services. Software engineering methods in the studies mainly considered issues related to interoperability, software reusability, and platform independence. Service-oriented and intelligence-based software engineering approaches addressed the challenges. Eventually, the studies indicate that intelligence-based software engineering approaches have been seen as generic software engineering methods for designing and developing IoT applications software. Furthermore, component-based and object-oriented software engineering approaches are open to being investigated further as future work.

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THE MODERATING ROLE OF IT AUDITING ON INTEGRATED PHARMACEUTICAL LOGISTICS SYSTEM (IPLS), USER SATISFACTION AND LOGISTICS PERFORMANCE OF ETHIOPIAN HOSPITALS

ABSTRACT

Health is one of the crucial elements for the development of any country and the well being as well as productivity of its citizens. Controlling and auditing the risk that may come from deploying IT for health provision is a key issue in society. This study will assess the moderating role of IT auditing on the relationship among IPLS, user satisfaction and logistics performance of health commodities in Ethiopian hospitals. Data will be collected from respondents in selected Public and Private Hospitals throughout the country using questionnaires by adopting multi stage simple sampling process (Regions, Zones, and Woredas are used to trace hospitals). The study will employ explanatory research design with quantitative approach. The data collected will be analyzed using correlation and regression analyses to investigate the effect of the independent and moderating variables on the dependent variables. The study will have significant contributions for academics, practice, policy and research.

Key words: System Quality, Information Quality, Service Quality, User Satisfaction, Cultural factors, HIV/AIDS Commodities

INTRODUCTION

Information technology (IT) and the information system developed using IT is changing the way business is being conducted. Amoroso *et al* (2015) stated that senior management and business managers do have concerns about computer based information systems (ISs) because in the contemporary business environment, such systems are the lifeblood of any large business. However, Kim and Hu (2019) stated that current research does not pay sufficient attention to the complexities and interrelationships between different aspects of supply chain (SC) integration and the role of ICT in improving different elements of SC performance. Nguyen *et al* (2019) stated that in the context of market globalization, intensified competition and technological breakthrough, businesses have long recognized the critical role of effective IT supported supply chain management in achieving competitive advantage. This is so rare in relation to the health sector and supply chain of medicines. Aditya *et al* (2018) also stated that in the era of digital transformation, IT risk is the main focus for top management because IT risk will not only threaten the IT environment but can also make the company lose its overall business. They further argued that limited knowledge of top management about IT makes it difficult for them to evaluate the effectiveness of IT implementation and, therefore, IT audit became so important to help management to evaluate that IT implementation does not create unacceptable risks by businesses. Amoroso *et al* (2015) described IT auditing as the process of collecting and evaluating evidence to determine whether an information system safeguards assets, maintains data integrity, achieves organizational goals effectively and

consumes resources efficiently. Health is one of the crucial elements for the development of any country and the well being as well as productivity of its citizens which is one of the sectors transformed by information systems. To achieve successfully the Millennium Development Goals, the Government of Ethiopia has developed various programs and strategies in the health sector, one of which is the integrated pharmaceutical logistics system (FMOH, 2010). Integrated pharmaceutical logistics system (IPLS) is the system that can ensure access to quality, safe, affordable and uninterrupted supply of vital and essential medicines (Nigussie, 2017). He further stated that IPLS is the term applied to the single pharmaceuticals reporting and distribution system. It aims are to ensure that patients always get pharmaceuticals they need. IPLS integrates the management of essential pharmaceuticals including pharmaceuticals that were used to be managed vertically and it is the primary mechanism through which all public health facilities obtain essential and vital pharmaceuticals (FMOH, 2010). IPLS integrates the supply chain management of all types of pharmaceuticals (medicines, medical supplies and equipment, and laboratory chemicals and reagents) in the public health sector. In late 2006, the Ministry approved the Pharmaceutical Logistics Master Plan (PLMP) through which, Pharmaceuticals Fund and Supply Agency was established in 2007 by Proclamation No. 553/2007. To execute this mandate, PFSA, in collaboration with different partners who were working in the health sector developed and began implementing the Integrated Pharmaceuticals Logistics System (IPLS) in 2009.

Prior studies tried to assess only the IPLS implementation process as well as challenges and opportunities without indicating what factors influence the performance of IPLS. No prior studies were conducted to observe the antecedents and consequences of IPLS performance involving moderating and mediating variables in a way this study has been designed. This study has also introduced the influence of culture of the people involved and its effect on the performance of IPLS on top of other factors (Romi, 2011). In addition, one basic IT governance tool which influences the utilization of IT in any organization is IT auditing (Woda, 2002). Pathak (2005) described IT auditing as having acquired pre-dominance with the extensive use of information and communication technology in the information processing area. IT auditing is, therefore, defined as the process of collecting and evaluating evidence to determine whether an information system safeguards assets, maintains data integrity, achieves organizational goals effectively and consumes resources efficiently. Hence this research will, therefore, be conducted to assess the moderating effect of IT audit effectiveness on the relationship among IPLS, users' satisfaction and the logistics performance of health commodities in selected private and public Hospitals in Ethiopia. The research will answer the following specific research question.

1. What is the influence of **IT audit effectiveness** on IPLS performance?
2. What is the role of **IPLS performance** on user satisfaction in Ethiopian hospitals?
3. What is the effect of **cultural factors** on user satisfaction in using IPLS in Ethiopian hospitals?
4. What is the influence of **user satisfaction** on logistics performance of Ethiopian hospitals?

LITERATURE REVIEW, RESEARCH MODEL AND HYPOTHESES DEVELOPMENT

In this part, the background literature, theories and research models are used to develop the research hypotheses for the study. This will lay the foundation to answer the research questions of the study.

Role IPLS for Logistics Performance

Real-time tracing and supply chain management of all drugs in a hospital is a challenge in healthcare which requires further developments in information and communication technologies. Berhanemeskel *et al.* (2016) stated that supply chain management of essential health commodities involves a series of activities to guarantee the continuous flow of products from the manufacturer to consumers. Tilahun (2014) also asserted that an accurate quantification based on reliable data is essential for all health commodities but more so for HIV/AIDS related commodities because uninterrupted access for patients must be ensured. Mudzteba (2014) stated that pharmaceutical logistics data are collected, processed, and reported through IPLS, increasing the likelihood of an adequate supply of HIV/AIDS commodities. To contribute to the objectives of an organization, an information system should fulfill some key requirements and this should be evidenced through proper IT auditing (Amoroso *et al*, 2015). Information system effectiveness is the extent to which a specific information system actually contributes to achieving organizational goals, that is, its effect on organizational performance (Hamilton and Chervany, 1981). Prior studies on IPLS emphasized on system implementation predominantly. Those that relate with organizational performance assess only one case study or very limited case Hospitals. Most of the studies were also descriptive by their nature of design. Lastly, almost all studies were limited to public hospitals only in Addis Ababa, the Capital City. In this study, the moderating role of IT audit effectiveness influencing IPLS performance and its effect on logistics performance of HIV/AIDS commodities will be assessed in public and private hospitals with reference to selected Zones and Woredas throughout the country. The study is believed to bridge the gap in previous studies. In addition, culture is believed to influence user satisfaction and system implementation which is a new construct obtained from other studies and incorporated in this study.

Research Model and Hypotheses

In this study, explanatory factors that influence IPLS performance and its effect on logistics performance of HIV/AIDS commodities in selected public and private hospitals will be assessed. The study is believed to bridge the gap in previous studies.
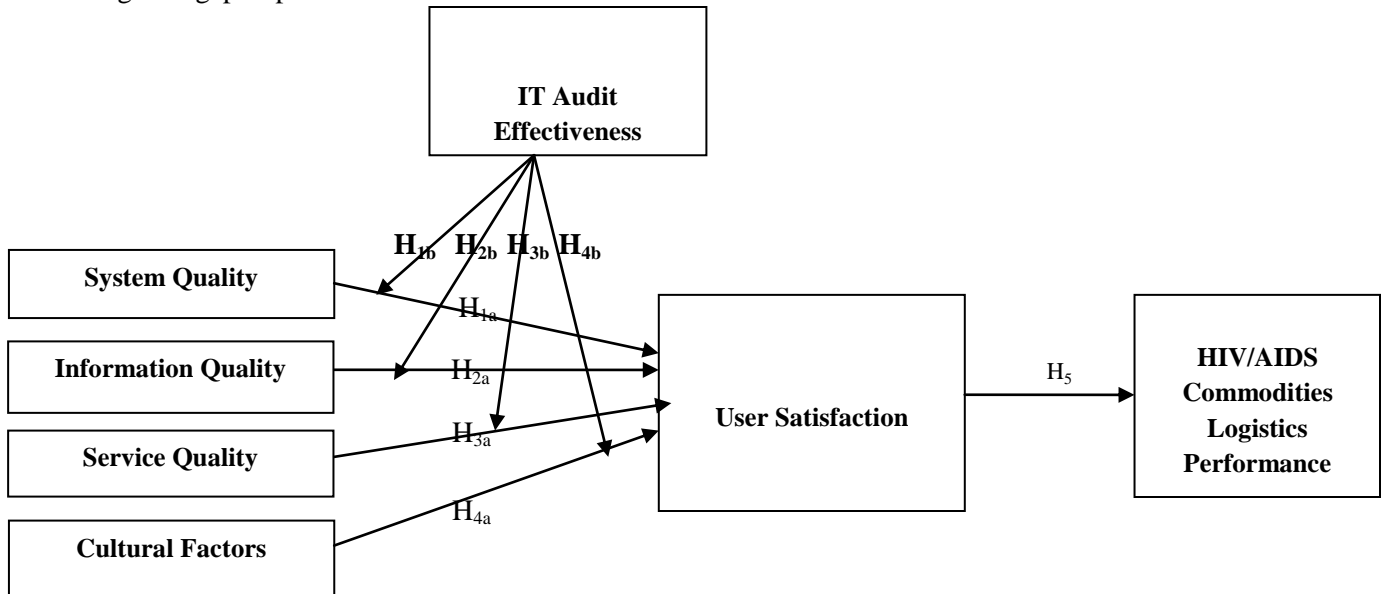

Figure 1. The Conceptual Framework (Based on Sirsat and Sirsat, 2016)

The conceptual framework illustrates how IT Audit effectiveness moderates the relationship among the independent variables (IPLS performance which includes system quality, information quality, service quality, and team culture) and the mediating variable (user satisfaction on IPLS) influence logistics performance of hospitals (the dependent variable). Next is presented the detailed description of each construct and hypotheses of the study. Next is presented the detailed description of each construct and hypotheses of the study.

a. System Quality

According to Halawi *et al*. (2007), Dreheeb, Basir and Fabil (2016) and Sirsat and Sirsat (2016) the term system quality reflects excellence, value, conformity to specification and quality meeting customers' expectations. The value of information system can be realized by improving profit margins for the organization, providing easy-to-use and meaningful applications, and designing easily maintainable system. Thus system quality is an important aspect in IS success. Measures of the system quality which have been used in the literature are flexibility, stability, reliability, usefulness, user-friendly interface, ease of use and response time. Access and retrieval of information when needed, to meet work demands and to return requests quickly have been noted to be inherent to system quality. Hence, according to Halawi et al. (2007), Dreheeb, Basir and Fabil (2016) and Sirsat and Sirsat (2016) system quality positively correlates with user satisfaction and better benefit realization in any organization. Hence, the same applies to IPLS and it can be hypothesized as follows:

H1a: IPLS Quality significantly and positively influences user satisfaction.
H1b: IT Audit Effectiveness positively influences the relationship between IPLS Quality and user satisfaction.

b. Information Quality

Halawi et al. (2007), Sirsat and Sirsat (2016) and many others in Information systems research argued that information system quality concept is related to system output that is useful for business users. The most important informational insufficiency that managers suffer from is plenty of irrelevant information. Information quality problems, such as incorrect information due to program or data errors and irrelevant information arise due to changed user requirements. Some important dimensions studied under Information quality like relevance, understandability, accuracy, conciseness, completeness, being up to date (timeliness) and usability.

Sirsat and Sirsat (2016) further stressed that information quality refers to the ability to acquire information that is sufficient, that meets end-user needs, and is comprehensive in nature. Many researchers in different studies have measured information quality and the most common measures were of timeliness, completeness, ease of understanding, relevance, security, consistency, accuracy and personalization, importance, usefulness, readability etc. Sirsat and Sirsat (2016) found in their empirical study that measuring system characteristics like the content of database, aggregation of details, human factors, response time, and system accuracy positively correlates to user satisfaction and system performance. Hence, for IPLS, it can be hypothesized as follows:

H2a: IPLS information Quality significantly and positively influences user satisfaction
H2b: IT Audit Effectiveness has positive effect on the relationship between IPLS information Quality and user satisfaction

c. Service Quality

The dimension service quality represents the quality of the support that the users receive from the IS department and IT support personnel. Organizational success is delivered by the service provider. On time and error free performance by IS unit improves organizational efficiency (Halawi et al. 2007; Romi, 2011; Sirsat and Sirsat, 2016). Some of the dimensions that are used to measure this success by most of the researchers include Assurance, Empathy, Flexibility, Interpersonal Quality, Intrinsic Quality, IS Training, Reliability, Responsiveness. IPLS services, which are part of the overall IS services, will become better aligned with organizational goals, resulting in improved quality of decision making and improved profitability, better expectancy of customer demands and more accurate sales forecasting (Halawi et al. 2007; Romi, 2011; Sirsat and Sirsat, 2016). Hence, it can be hypothesized as follows:

> *H3a: IPLS Service quality significantly and positively influences users' satisfaction*
> *H3b: IT Audit Effectiveness positively influences the relationship between IPLS Service quality and users' satisfaction*

d. Cultural Factors

In many systems literature, cultural factors are believed to influence the level of diffusion and utilization of an information systems project. IPLS implementation could also be influenced by the national cultural factors which in turn will affect the organizational culture where the IPLS is operated in. Al-Jumeily and Hussain (2014) identified three primary continuums drawn from the national cultural dimensions theory of Hofstede that are used to identify the differences in the cultural factors—individualism/collectivism, uncertainty avoidance, and power distance.

Individualism/Collectivism is the degree to which individuals are integrated within any group. In individualism, the emphasis is on individual roles and rights, where individuals are expected to stand up for themselves, their own family and their own affiliations. In contrast, in collectivism, individuals behave as members of an organization or group, so that their family is that group or organization to which they pay unquestioning loyalty.

Uncertainty Avoidance is defined as the tolerance of a society for uncertainty. It measures the extent of coping with anxiety by avoiding uncertainty. High uncertainty-avoidance cultures implement rules and laws to support plans that are followed step-by-step to minimize unknown and ambiguous circumstances. On the other hand, low uncertainty-avoidance cultures have as few rules as possible, they tolerate changes and accept a changeable environment and situations; these cultures tend to be pragmatic cultures.

Power Distance reflects the way people accept and perceive power differences. High power-distance cultures accept autocratic power relationships, where people are not equal to each other, and their positions are classified hierarchically from superior to subordinates (Akour et al. 2006). In contrast, low power-distance cultures experience more democratic relationships, and equality is practiced by all members of the society, who have the right to criticize and change the decision making of those who are in power (Teo *et al*. 2008). As Romi (2011) affirm, people use technology within a cultural and social context, and these influence how humans behave towards technology. Often a whole host of factors differ across cultures, and these factors include social taboos, political and legal constraints, together with religious, ethical and traditional values. Therefore, technology users across the globe have different

perceptions, styles of thinking, cognitive and cultural values, and assumptions. Hence, it can be claimed that the above argument applies to IPLS as one category of system and it can be hypothesized as follows:

H4a: Good Culture of using IPLS significantly and positively influences user satisfaction
H4b: IT Audit Effectiveness positively influences the relationship between IPLS users culture and users' satisfaction

e.   User Satisfaction and Organizational Impact

Halawi et al. (2007), Dreheeb, Basir and Fabil (2016) as well as Sirsat and Sirsat (2016) stated that user satisfaction is defined as the recipient's response to the use of the output of an information system. They mentioned studies which found that user satisfaction closely related with user attitude; therefore, studies which include user satisfaction as a success measure should ideally also include measures of user attitudes. Sirsat and Sirsat (2016) further asserted that user satisfaction can be measured indirectly through information quality, system quality, and other variables. Hence it is used as a mediating variable between system performance and organizational performance (Halawi et al. 2007; Dreheeb, Basir and Fabil 2016). According to Sirsat and Sirsat (2016), organizational impact represents the firm-level benefits received by an organization because of Information System applications. Measures of organizational performance which might be appropriate for measuring the contribution of IPLS is return on investment for profit oriented business organizations. Several authors have developed constructs to measure IPLS impacts on organizations. The success of information systems impacts not only on firm performance but also on industry structure. As stated by Kim and Hu (2019), ICTs are important to logistics because they provide the right information at the right time and place. Operating cost reduction, staff reduction, productivity gain, increased revenues and profits and increased work volume (productivity). A cohesive, well-performing public health supply chain helps build the foundation for a strong pharmaceutical management system, provides essential information for managing health programs and financing mechanisms, and helps to achieve the level of accountability exemplified in the commercial sector. Integration has helped companies learn to deliver good quality products efficiently, on time, and securely to their customers. These improvements have translated into increased profits, more viable companies, and better customer service. Integrated supply chain links all the actors involved in managing essential health commodities into one cohesive supply chain management organization. Integration helps client's access quality healthcare services and supplies (Berhane, 2017). Hence, it can be hypothesized as follows:

> *H5: User satisfaction of IPLS significantly and positively influences Logistics performance of HIV/AIDS commodities.*

RESEARCH METHODOLOGY

Research Design and Approach

The underlying philosophical assumption used here lies in the positivist paradigm. The choice for the positivist paradigm is done because of the fact that the purpose of the research is to develop and validate an empirical model which tests a reality existing out there. The type of research design to be used is an explanatory research whereby the influence that Auditing IPLS use will have on user satisfaction and the logistics performance of the HIV/AIDS commodities in the selected Ethiopian hospitals. Explanatory studies would help manipulate the independent variable to influence the mediating and dependent variables. Explanatory research determines the causal relationships among variables (Saunders et al.,

2012). A quantitative research method using survey questionnaire will be used to conduct this study. As the number of respondents reached will be large enough, it is considered to limit the study using quantitative data only. The units of analyses for this study will be pharmacy professionals of the hospitals to be selected who use the IPLS for their day to day operations.

Target Population and Sample Selection

The target populations for this study are Public and Private Ethiopian hospitals that are currently using IPLS in their pharmacies. The governance structure of Ethiopia divides the country first into Regions (13 in number), then Zones within each region and Woredas within the Zones. Hospitals are available as low as Woreda level making this study highly comprehensive. In selecting sample pharmacies at Woreda level hospitals, the study will employ multi step purposive and simple random sampling. Firstly, some five administrative regions will be selected purposively taking into account their size, pace and stability of the region and representativeness. For instance, Amhara and Oromia regions alone will constitute more than 50% of the whole population of the country. Adding some two or three other regions will make the study quite representative of the whole country. Once the Administrative Regions are identified for the study, to select Zones and Woredas, simple random sampling method will be applied. Finally, after the target hospitals are identified for the research, census of pharmacy professionals in the hospital will be taken.

Data Type and Source

To collect the data from the primary sources, self administered questionnaires will be distributed for the target respondents identified above. Likert scale questions on five point scale (strongly disagree to strongly agree) will be used to measure the variables of the study. The instrument will be customized from prior studies and it will also be pretested for its applicability in the study area. Head of the hospitals (the Medical Director) will be approached having support letter from the university the researchers work in to obtain consent and permission of the respondents to undertake the data collection process. Then, the questionnaires will be distributed for and collected in person from the respondents resulting in higher response rate. The respondents will be informed in the survey instrument that the data would be used only for academic purpose and assured to feel free that their responses would be held confidential. In addition, they will be seriously informed that the data wouldn't be analyzed in isolation, rather analyzed altogether with the responses of other respondents to assure that they could not be identified individually. These all assurances in the survey instrument would help to minimize the Common Methods Bias (CMB) of collecting data about the independent and dependent variables from the same audience.

Method of Data Analysis

The quantitative data will be entered and analyzed using AMOS software using Structural Equation Modeling (SEM) approach. Descriptive statistics (mean and standard deviation) will be computed and summary results will be presented using tables and graphs. Correlation coefficient will be computed to see the association between aspects of IPLS performance with user satisfaction and the logistic performance of HIV/AIDS commodities. Path Analysis using SEM will also be undertaken to test the effect of the independent variable (IPLS Performance) and the moderating variables (IT audit effectiveness) on the mediating variable (user satisfaction) and the dependent variable (Logistics performance of health commodities). The reliability of the data will be checked using Confirmatory Factor Analysis (CFA) of the standardized survey instruments to be used. The Validity of the research

will also be checked by using a survey instrument adopted from prior studies, that will be pre-tested for completeness and use in Ethiopian context. This approach will address both face validity, construct validity and content validity issues.

CONTRIBUTION OF THE STUDY

Different studies indicated that 70 to 80 percent of projects are failed and IPLS implementation is one such project whose effectiveness should be evaluated in Ethiopian Hospitals. This costs a lot all stakeholders. Hence, the findings of this study will have significant contributions for various stakeholders. Firstly, practitioners will use the findings of this study in improving the system performance so that key health commodities will swiftly reach the beneficiaries without loss and in a useful manner. This will have several benefits such as saving lives, cost savings as well as mental wellness due to ease of getting the right medicines at the right time. Secondly, as a policy maker, Ministry of health and health bureaus of regions and other health related decision makers will use the findings of this study in their future enforcement logistics plans of health commodities. .Thirdly, it will also help academics both at undergraduate and graduate levels to revise their curricula and provide relevant health logistics related content for the students. Finally, it will serve as stepping stone for future research in this and similar areas. As indicated in the background, national level multi factor causal research is rare and other studies replicating the same research, adding new variables and new organizations such as Clinics and Health Centers in the country could be conducted using this one as a reference.

POTENTIAL LIMITATIONS OF THE STUDY

The study will focus on assessing the effect of IPLS on the logistics performance of HIV/ AIDS commodities in the Hospitals to be selected as to make the research work more manageable. This is because such medicines are so critical that can't be interrupted and there is large number of patients treated in the hospitals. In addition, this study may have some limitations. Firstly, the respondents may be busy to complete questionnaires. Close follow up effort will be put to maximize collection of questionnaires and minimize this limitation. Another limitation could be respondent bias where the respondents might give the socially desirable answers. The large dataset would help to minimize this part of the limitation. Making it a cross sectional study and not including qualitative data may also have some influence on the findings of the study. Future research may consider this issues and expand the findings of this study.

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ASSESSING THE ROLE OF INFORMATION TECHNOLOGY GOVERNANCE (ITG) ON THE PERFORMANCE OF PUBLIC HIGHER EDUCATION INSTITUTIONS IN ETHIOPIA

1. INTRODUCTION

Information technology (IT) usage is part of any modern organization be it a business, governmental or nongovernmental one. In a typical organization, investments on desktop and laptop computers, printers, telecommunication networks, database management systems and some specialized information systems (accounting, manufacturing, human resources, customer relationship, supply chain, etc) are commonplace. Bianchi *et al* (2021) stated that organizations have been using IT to automate and perform process integration, connecting the enterprise with customers, suppliers and distributors to obtain sustainable competitive advantage. Moreover, the pervasive use of technology has created a critical dependency on IT that demands considerable attention to IT Governance (ITG). Ghildyal and Chang (2017) argued that IT governance is an essential part of enterprise governance which is driven primarily by demand for transparency across enterprise IT related risks and protection of shareholder value. Aditya, *et al* (2018) also share the above view stating that in the era of digital transformation, IT risk is the main focus for top management, especially in business decision making. These clearly indicate that IT governance critically influences firm performance. Lazic *et al* (2011) also asserted that the fundamental importance of information technology (IT) in today's business operations can hardly be refuted and while IT spending is constantly rising, the continuous debate surrounding the IT productivity paradox has decreased.

As business complexity and regulatory requirements grow, the need for and investment on IT will be expected to increase (Parent and Reich, 2009). But whether these investments are really creating the value they are intended to create and whether risks related to such investments and operations are properly managed do not seem well assessed. Sayana (2002) argue that senior management and business managers do have concerns about computer based information systems (ISs) because such systems are critical to such large organizations as they do not merely record business transactions, but actually drive the key business processes of the enterprise. In many organizations, information technology (IT) has become crucial in the support, sustainability and growth of the business. This pervasive use of technology has created a critical dependency on IT that calls for a specific focus on IT governance. IT governance consists of the leadership and organizational structures and processes that ensure that the organization's IT sustains and extends the organization's strategy and objectives.

The practitioner and academic literature has paid increased attention to the practice of information technology (IT) governance by boards of directors and their executive management who represent top management of any organization. However, it seems that top management of many organizations do not explicitly practice a formalized style of IT governance, and of those that do, many face significant challenges. The potential impact of ineffective IT governance is clear, with organizations spending an increasing amount on IT.

Ethiopian Companies are spending huge amount of money on IT as indicated for the developed economies such as the USA. Worku (2010) for instance stated that harnessing its leadership with advanced banking technology, Dashen Bank signed an agreement with iVery, a South African electronic payment technology company, for the introduction of mobile commerce in April, 2009. Personal observation of the researcher (also a faculty member) indicated that Addis Ababa University has invested a lot on its information system to support online content delivery, student services and facilitate all its operations. The same pattern applies to almost all public and private universities in Ethiopia.

There is continuing debate over the contribution of IT towards business value creation in all types of organizations, (Lazic *et al*, 2011) for instance. It is repetitively claimed that IT capability has increased tremendously but not translated into bottom line figures such as profitability, productivity, cost reduction etc. While it was described in various terms such as IT management, IT resources management or IT leadership in the past, today emphasis has been on IT governance instead of IT management/leadership. While there are studies conducted on aligning business and IT strategies in organizations, there are only limited studies addressing value creation aspect and what hiders such value creation process.

The study is motivated by the fact that IT and its application in business (to be used synonymously with IS from audit and governance perspectives) being one key resources that needs to be governed by top management for organizational value creation but being at the same time the least understood of the key assets in an enterprise (Weill and Ross, 2004). These resources being least understood will have significant positive as well as negative impact on organizational survival and success. It is often reported that boards and executive management are suffering from IT attention deficit (Parent and Reich 2009). Why top managements of organizations behave as such depends on several contingency factors which are not sufficiently explored through empirical studies, especially from developing economies point of view.

This study is also motivated by the fact that IT related risks are critical for organization resulting in loss of value, litigation and decline in market share as evidenced by Parent and Reich (2009) who have reported on the importance of IT investment in the modern business environment as well as related risks due to failure of these investments. They cited as an example that U.S. companies spend as much on information technology each year as they do on offices, warehouses, and factories combined and they also claimed that IT represents about two-third of all capital spending and the average enterprise's IT investment is now greater than 4.2% of annual revenues (Parent and Reich, 2009). As a result of these large investments, the consequences of any disasters are likely to be profound and lasting.

Finally, the study is motivated by the diversity and scattered nature of mechanisms that bring proper IT governance. While many studies mentioned IT governance processes, structures and relational mechanisms as means of getting proper IT governance (DeHaes VanGrembergen, 2005), others proposed IT auditing and audit committees as one critical means of IT governance (Parent and Reich, 2009). Even in this regard, except very few exploratory studies indicating future studies, empirical

investigations are so scant. When we see the African and Ethiopian context, almost no studies were available. So this research will be undertaken to partially bridge this gap in the literature.

The need for proper governance of IT is evidenced by Chorafas (2009) who stated that the huge changes taking place in IT organization and management are driving people to pick up new skills, while the CIO's performance is increasingly judged by how far and how well he or she can be a business innovator and service-level designer. These points that are reflections of IT audit and governance tasks shall be empirically tested in Ethiopian context.

This is clear from the concern of Parent and Reich (2009) who stressed that they see no sign that the pace and size of IT investments will abate, nor that IT-based risk will cease to be a problem. This underscores the importance for Boards to act and act now if their companies are to minimize the effects of an ever-growing array of potential IT disasters which means a call for proper IT audit and governance. Unfortunately, many Boards pay little, if any, attention to IT investments, and they do not concern themselves with minimizing potential waste or risk in this area. Hence, top management seems to be suffering from an IT attention deficit. It can be claimed that Ethiopian Company boards and executive committee members can't be exceptions from those in the developed world. All these problems and concerns are related to the process of IT governance in organizations. As Weill (2004) claimed, IT Governance matters because it influences the benefits received from IT investments. He further claims that through a combination of practices (such as redesigned business processes and well designed governance mechanisms) and appropriately matched IT investments, top performing enterprises generate superior returns on their IT investments (up to 40% greater return than their competitors for the same investment).

In addition to IT governance processes, structures and relational mechanisms used by organizations, one basic IT governance tool that needs critical observation is IT auditing (Woda, 2002). Pathak (2005) described IS auditing (taken synonymously with IT auditing) as having acquired pre-dominance with the extensive use of information and communication technology in the business information processing area. IT auditing is, therefore, defined as the process of collecting and evaluating evidence to determine whether an information system safeguards assets, maintains data integrity, achieves organizational goals effectively and consumes resources efficiently.

Lazic *et al* (2011) argued that many organizations started with the implementation of ITG, but academic research within this area is still in its early stages, with theoretical models explaining the impact of ITG on business performance being unavailable.

Bianchi *et al* (2021) stressed that IT governance practices and their impact on organizational performance of universities are not researched well. This will be more severe in public universities as Ghildyal and Chang (2017) called for re-establishment of the Public Sector IT governance in order to reach the vision and mission of our Public Sector Objectives. They added that the IT governance in public sectors is not always practical, resulting in a range of issues, which hinder the organization performance, namely: Staff unable to access integrated data due to multiple disconnected systems; Proliferation of

manual based-systems; Lack of semantic integration; Mandraulic effort in obtaining a snapshot of data from multiple systems.

In developing economies like Ethiopia, empirical studies on auditing of IT and IT governance processes and their impact on organizational performance, particularly in universities are scarce. Such studies are scarce even at African level let alone in Ethiopia as evidenced by Mbarika *et al* (2005) indicating that research with a focus on Sub-Saharan Africa (SSA), a major region within the world's second largest continent, is almost non-existent in mainstream information systems areas. Therefore, this study has been designed to fill the gap stated in here and contribute new insight both to the academics and the practice of IT auditing and IT governance and its impact on organizational performance with specific emphasis on public universities in Ethiopia.

The research problem to be addressed in this research is investigating how Ethiopian Universities are handling the IT Governance agenda and how IT auditing can be used in the IT governance process. This will be followed by assessing how IT governance performance influenced organizational performance such as customer satisfaction, quality of decisions made and cost savings realized. This problem will be investigated in light of the theories indicated in the next part (Strategic Choice Theories, Institutional Theories and Stewardship/Agency Theories).

The specific questions to be answered are:
1. How are Universities dealing with IT governance problems?
2. What is the association between IT governance performance and organizational performance?
3. What is the role of IT auditing in IT governance process?

2. LITERATURE REVIEW, RESEARCH MODEL AND HYPOTHESES
2.1. IT and IT Governance in Organizations

The performance of many organizations relies on the effective use of Information Technology (IT). A mechanism to achieve this goal is the introduction of IT Governance to control and manage IT. Information Technology (IT) has become pervasive in current dynamic and often turbulent business environments. While in the past, business executives could delegate, ignore or avoid IT decisions, this is now impossible in most sectors and industries (VanGrembergen and DeHaes, 2008). They further claimed that the dependency on IT becomes even more imperative in this knowledge-based economy, where organizations are using technology in managing, developing and communicating intangible assets such as information and knowledge. These facts will enable us to conclude that IT becomes not only a success factor for survival and prosperity, but also an opportunity to differentiate and to achieve competitive advantage.

In many organizations, information technology (IT) has become crucial in the support, sustainability and growth of the business. This pervasive use of technology has created a critical dependency on IT that calls for a specific focus on IT governance (VanGrembergen and DeHaes, 2008). DeHaes and VanGrembergen (2009a) stated that IT governance is a concept that recently emerged and became an integral aspect within the complex realms of IT. IT governance consists of the leadership and

organizational structures and processes that ensure that the organization's IT sustains and extends the organizations strategy and objectives. Peterson et al. (2002) stressed that executives recognized that getting IT right this time will not be about technology, but about governing IT. Traditionally defined as the locus of IT control, scholars have recently questioned whether the concept of IT governance is simply about centralization and decentralization. Provided that IT is considered as a strategic partner to an enterprise implies that it is a top management and board responsibility to properly govern IT. Hence, IT governance shall be considered as an organizational phenomenon to be analyzed by and dealt with organizational behavior theories (Jewer, 2009). In the next paragraphs will present definition and roles of IT governance on business performance. Weill and Ross (2004) identified six key assets namely, human, financial, physical, intellectual property, IT, and relationships that must be governed to create value.
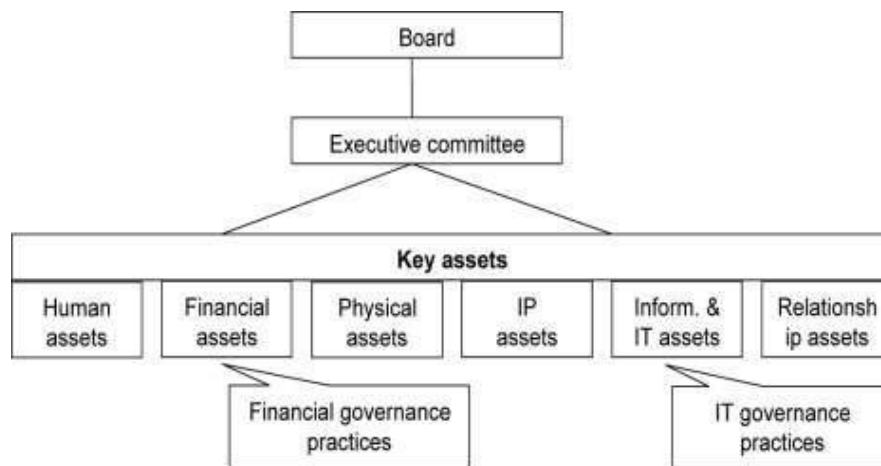

Figure 1: The Assets Firms govern to create value (Weill and Ross, 2004)

Jewer (2009) stated that IT governance literature can be classified into two separate streams. The first focuses on the design of decision-making structures at the managerial level, while the second focuses on the role of the board. The term 'governance' in IT has been used to broadly describe the policies, structures, and management processes involved in managing IT functions (Jafaar and Jordan, 2009). Jewer (2009) also stated that Board IT governance is the provision of oversight of business/IT strategic alignment; IT value delivery; IT resource management; IT risk management, and; IT performance management and stressed that as with corporate governance, boards have a fiduciary duty and a duty of care in IT governance being responsible for acting honestly and in good faith and for spending time to make informed business judgments. IT governance can be deployed using a mix of structures, processes and relational mechanisms (Peterson, 2003; DeHaes and VanGrembergen, 2008; Symons, 2005). Examples of structures, processes, and relational mechanisms include:

- *Structures.* CIO on Board, executive management committees, IT strategy committee, IT leadership committees, and IT steering committee(s).
- *Processes.* Strategic information systems planning, balanced (IT) scorecards, information economics, service level agreements, control objectives for information and related technologies and the IT infrastructure library, IT portfolio management, and demand management.

- *Relational mechanisms.* Active participation and collaboration between principal stakeholders, partnership rewards and incentives, business/IT co-location, cross-functional business/IT training and rotation.

2.2. IT Auditing and IT Governance

Hardy (2009) asserted that those who are responsible for IT functions that deliver IT services have realized they no longer work in a vacuum. Compliance has opened the doors to IT processes and exposed the need to tighten key controls. IT governance maturity assessments have become widespread, showing gaps between expected goals and process capability. This is making executives realize the need to run IT more like a business and to drive process and infrastructure improvement. CIOs are no longer working in isolation; they are acting as the bridge to the business and as part of an executive team governing IT investments and service delivery. Roles and responsibilities between IT and the business customers are being clarified. So, what does this all mean for IT auditors and what is their role in IT governance are the questions that are relevant and timely to ask.

Ohri (2008) traced the demands for IT auditing stating that the last few years have been an exciting time in the world of IT auditing as a result of the accounting scandals and increased regulation. IT auditing adds security, reliability and accuracy to the information systems integral to humans' lives associating IT governance to IT auditing compliance issues. Carlin and Gallegos (2007) stated that the IT auditor can help organizations implement control structure processes such as Control Objectives for Information and Related Technology (COBIT), the Committee of Sponsoring Organizations of the Treadway Commission (COSO), and International Organization for Standardization (ISO) standards 9000, 9001, 17799, and their amendments. In addition, the IT auditor can help maturing organizations successfully attain IT governance as part of their internal audit structure or as an external audit by public accounting firm or government audit organization.

Iliescu (2010) supports this stating that auditing IT Governance needs more business knowledge than regular Information Systems (IS) audits because the IS auditor has to evaluate how IT is enabling the business strategy. IT is no longer seen as support process, but because a project is not enough to respond itself to a business outcome, multiple projects should managed together as programs. Iliescu (2010) further recommends that when auditing IT Governance, the IS auditor should also consider relationships within the organization (strategically, financially and/or operationally) and obtain information on the strategic plan, including the IS strategic plan. Sayana (2004) also stated that in enterprise information systems scenario, the IT audit will be critically relevant and the scope of IT audit needs to be broadened to cover IT governance aspects. The auditor is then expected to adopt what is called a risk-based approach. While there are risks inherent to information systems, these risks impact different systems in different ways. The risk of nonavailability even for an hour can be serious for a billing system at a busy retail store. The risk of unauthorized modification can be a source of frauds and potential losses to an online banking system.

Hardy (2009) also approved this stating that IT auditors now have an opportunity to be agents for change and providers of assurance to management as they have expert knowledge about IT risks and

controls, which is in high demand and in short supply, but to be effective, they need to be business-savvy and able to engage with top management. IT auditors need to get involved; be constructive; and use open, commonly accepted practices, frameworks and standards. The days of hidden checklists are over—an open-book mentality that enables self-assessment and passes on knowledge to business and IT managers is needed. IT auditors can perform a number of key roles (Hardy, 2009):

- Initiating IT governance programmes in ways such as explaining IT governance and its value to management, defining the role for audit participation, challenging proposed activities and actions and providing advice regarding controls and risk management.
- Assessing the current state such as target-state positioning and gap priorities.
- Planning IT governance solutions in ways such as providing independent assurance that issues identified are valid, business cases are subjectively and accurately presented, and plans appear achievable.
- Monitoring IT governance initiatives in efforts such as providing independent assessment of the overall efficiency and effectiveness of IT governance initiatives, assessing the effectiveness of audit's contribution to the initiative, using positive results to improve current audit-related IT governance activities, and adapting as well as improve audit's approach to future IT audit activities.
- Helping make IT governance business as usual by providing objective and constructive input, encourage self-assessments, and provide assurance to management that governance is working effectively, and provide ongoing audits based on an integrated governance approach.

All the above points indicate that there shall be considerable change in the way the auditor's role is perceived by the auditor as well as by the auditees. Hardy (2009) concluded that enlightened IT audit groups will set their own IT governance performance goals and measure their success and contribution by monitoring how well their efforts and audit recommendations have helped cause real and beneficial outcomes such as alignment between IT and business strategies, optimal cost of IT with good return on IT investments, clear view on how well IT is performing, IT meeting compliance requirements, and effective risk management programme. Bianchi et al (2021) in a recent study found out that the role of audit committee for IT governance in organizations was not properly assessed in the past which needs to be further studied.

2.3. Theories and Hypotheses Development

This research uses three theoretical perspectives and their integrated explanations to develop a theoretical framework of auditing IT and IT governance:

1. **Strategic choice theory** states that purposeful actions abound in organizations and organizational member have substantial leeway in shaping their own fates (Jewer, 2009).
2. **Institutional theory** addresses the issue of how and why organizational structures and processes come to be taken for granted and the consequences of this institutionalization process (Judge and Zeithaml 1992).

3. **Agency Theory** defines the relationship between the owners (principals) and managers (Agents). Wu (2006) argues that there exists information asymmetry between the agent and the principal and thereby divergence of interests between the two.

Jewer (2009), Jewer and McKay (2012) claimed that these theories can be used under different, partially-overlapping theoretical assumptions, and thus each theory gives only a limited explanation of the whole phenomena regarding IT governance and its consequences (organizational performance).

Based on the above theoretical review, a conceptual model for this research has been prepared below conceptualizing the IT governance process (indicating the variables and the key relationships) with additional literature review about IT governance and IT auditing. To explain IT governance, the three factors identified as critical by various experts (VanGrembergen and Dehaes, 2008 for example) are the following:
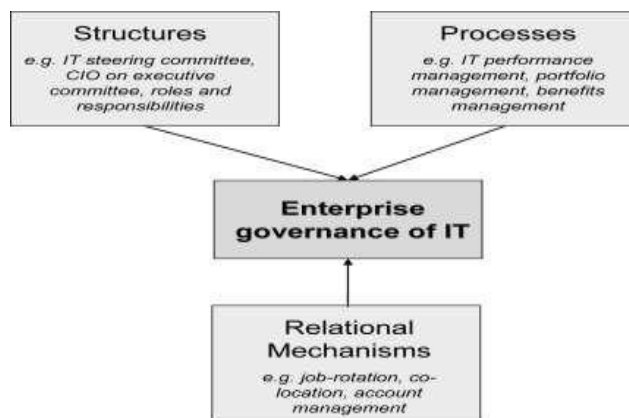
Figure 2: IT governance structures, processes and mechanisms (VanGrembergen and Dehaes 2009a)

Ko and Fink (2010) identified three possible means of achieving IT governance which are structures, processes and people. They combined mechanisms and structures together and added people as a new component. In the above diagram, the people components are part of the relational mechanisms (which are under structure) in this case. Once the factors that facilitate IT governance and the theories that explain this are identified, the relationship between IT governance performance and organizational performance can be observed as evident from the following model:

Figure 3: IT governance and Organizational Performance (DeHaes and VanGrembergen, 2009a)

The model presented for Business/IT alignment and business value from IT investments (organizational performance) will be equally applicable for other components of IT governance. Even if the above model can be used to related IT governance performance and organizational performance, it doesn't indicate the role of IT auditing in the relationship. The contribution of both types of audits (internal and

external audits) for IT risk governance has also been indicated by Parent and Reich (2009) as shown in the diagram below:
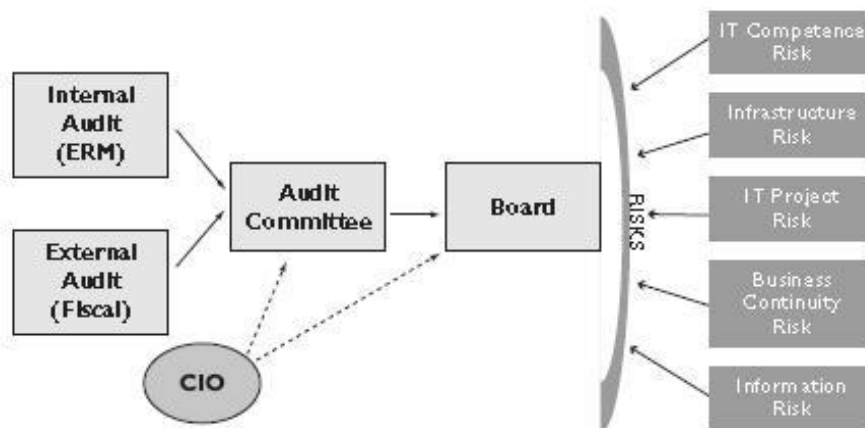
Figure 4: IT audit's role in IT risk governance (taken from Parent and Reich, 2009)

Parent and Reich (2009) stated that ideally, the audit committee triangulates input about IT risk governance: the organization's Chief Information Officer (CIO), the external auditors and internal auditors. This triangulation process is equally applicable to other components of IT governance (strategic alignment, value delivery, performance management and resource management). Empirical evidences are scant and not available in this area and it considered as a gap in the IT governance knowledge base worth detailed investigation.
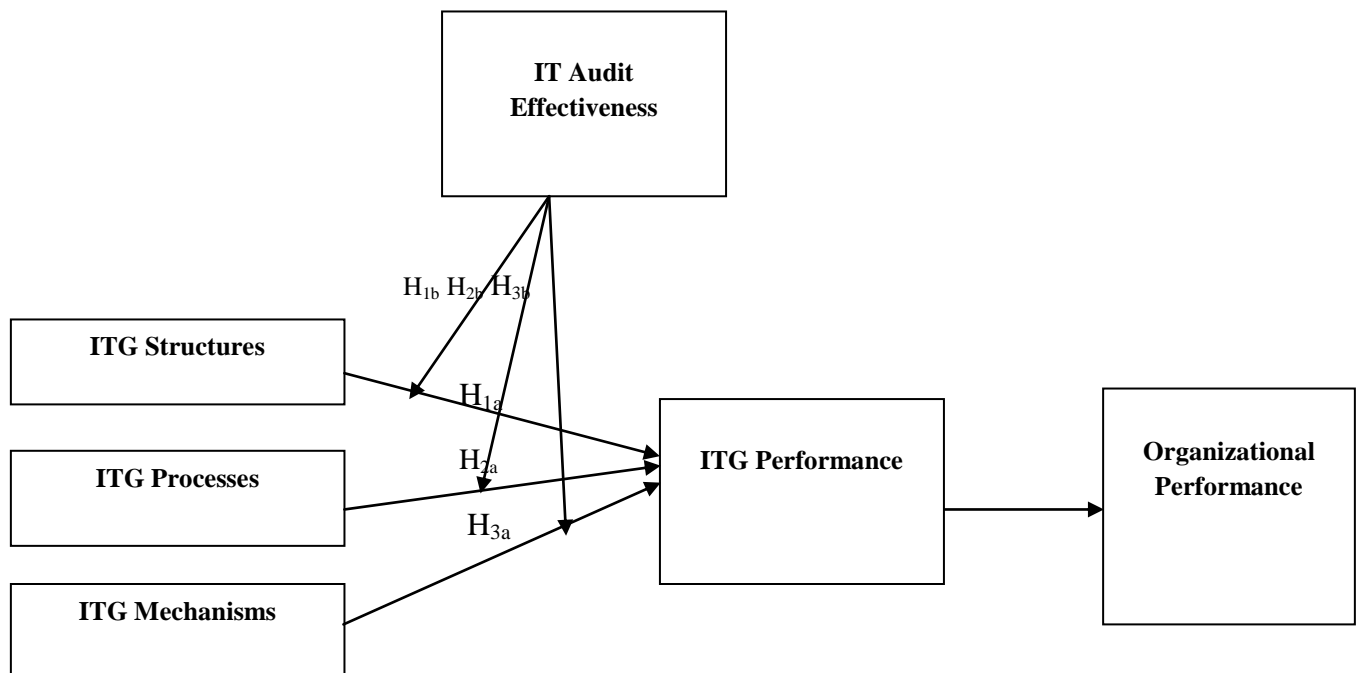
Figure 5: The Conceptual Framework (Developed by the researcher based on the literature)

2.3.1. ITG Structures and ITG Performance

IT governance structures include formal organizational structures and mechanisms for connecting and enabling horizontal, or liaison, contacts between business and IT management (decision-making) functions. Examples of IT governance structures include CIO on Board, executive management committees, IT strategy committee, IT leadership committees, and IT steering committees (Peterson, 2004; DeHaes and VanGrembergen, 2009a; Symons, 2005).

Jewer and McKay(2012) suggested that future research could investigate the role of committees such as IT strategic committees, as there is limited understanding of how or when IT Strategy Committees are effectively incorporated in board decision-making. For example, they mentioned a field study of a Belgian financial group found that even though the company had an IT Strategy Committee it "did not enable a more thorough and ongoing involvement of boards in IT governance (Jewer and McKay, 2012; DeHaes & VanGrembergen, 2005). The current study will help partially fill this gap leading to the next hypotheses using **Strategic Choice and Agency Theories** respectively as a lens.

Hypothesis 1a: IT governance Structures positively and strongly influence IT governance performance of Ethiopian Universities.

Hypothesis 1b: IT audit effectiveness positively moderates the influence of IT governance Structures on IT governance performance in Ethiopian Universities.

2.3.2. ITG Processes and ITG Performance

IT governance processes refer to formalization and institutionalization of strategic IT decision making or IT monitoring procedures. IT governance processes include strategic information systems planning, balanced (IT) scorecards, information economics, service level agreements, control objectives for information and related technologies and the IT infrastructure library, IT portfolio management, and demand management (Peterson, 2004; DeHaes and VanGrembergen, 2009a; Symons, 2005; Jewer and McKay, 2012). This implies the next hypotheses about the relationship between IT governance processes and ITG performance (success) using **Strategic Choice and Agency Theories** respectively as a lens.

Hypothesis 2a: IT governance processes positively and strongly influence IT governance performance of Ethiopian Universities

Hypothesis 2b: IT Audit Effectiveness positively moderated the influence of IT governance processes on IT governance performance in Ethiopian Universities

2.3.3. ITG Mechanisms and ITG Performance

IT governance relational mechanisms are the other mechanisms used to improve IT governance performance. The relational mechanisms are about the active participation of, and collaborative relationship among, corporate executives, IT management, and business management. Relational mechanisms are crucial in the IT governance framework and paramount for attaining and sustaining

business/IT alignment, even when the appropriate structures and processes are in place. These include active participation and collaboration between principal stakeholders, partnership rewards and incentives, business/IT co-location, cross-functional business/IT training and rotation (Peterson, 2004; DeHaes and VanGrembergen, 2009a; Symons, 2005). This results in the next hypotheses using **Strategic Choice and Agency Theories** respectively as a lens.

> *Hypothesis 3a:* *IT governance relational mechanisms positively and strongly influence IT governance performance of Ethiopian Universities*

> *Hypothesis 3b:* *IT audit effectiveness positively moderates the influence of IT governance relational mechanisms on IT governance performance in Ethiopian Universities*

2.3.4. IT Governance Performance and Organizational Performance

It is hard to pinpoint when the importance of IT governance became clear to the IT/IS professions (Weill and Ross, 2004; VanGrembergen and DeHaes, 2008). Gradually over a period of years, involving hundreds of conversations with managers and multiple research studies, it has been evidenced that IT governance is the most important factor generating business value from IT.

It has been argued that the management of IT, not just the quantitative investment in IT, can impact performance and there is ample empirical evidence showing that the quality of the IT department can impact firm performance (Jewer and McKay, 2012). Gartner introduced the idea of improving IT governance for the first time in its Top 10 CIO Management Priorities for 2003 (ranked third). Jewer and McKay (2012) stated that they did not find an empirical study directly examining the consequences of board IT governance during the literature review; however, they reported that evidence from a recent study on the relationship between proxies for board IT governance and firm performance suggests that a positive relationship exists (Lim, 2012). In fact, there is empirical support for a positive relationship between board involvement in corporate governance and financial performance (Judge & Zeithaml, 1992) and between proxies for board involvement in governance and firm performance. There is some research indicating that when boards provide richer information, executive management is more likely to engage in behaviors that are consistent with stockholders interests. This fact, therefore, demands further empirical studies to investigate the role of top management IT governance on firm performance. This will lead us to the last hypothesis for this study using **Institutional Theory** as a lens:

> *Hypothesis 4:* *IT governance performance positively and strongly influences firm operational performance (customer satisfaction, cost savings and facilitating decisions).*

3. RESEARCH METHODOLOGY
3.1. Research Design

The research will use explanatory design to answer research questions and test research hypotheses stated. As IT is used in facilitating organizational operations and securing strategic goals, the role of ITG on realizing such goals will be empirically tested using the data to be collected from the universities IT and other top management personnel. Such method has been used in many researches in the past and

was found to be appropriate design for cause-effect relationship type of studies (Jewer, 2009; Parent and Reich, 2009 for instance)

3.2. Research Approach

The study will employ only quantitative research approach. The data to be collected using Likert Scale questionnaires will result in a dataset to be analyzed using quantitative models such as correlation and linear multiple regression analysis. To reach large number of respondents from many universities limiting the study to quantitative approach is recommended as qualitative design will require intensive inquiry with very limited number of respondents.

3.3. Target Population and Sample Selection

The target population for this study will be Public Universities in Ethiopia. There are 32 public universities in four generations (based on year of establishment) in Ethiopia. Using proportionate stratified sampling technique, representative number of each generation of universities will be taken as target institutions for this study. Taking twelve universities (three from each generation of universities) is believed to be representative of the country as the universities are managed in the same manner under the supervision of a single ministry organization. The only difference among them is the year of establishment which is well considered when creating strata for sampling purpose. Once a university is identified as such, census of top IT and other management people will be taken as source of data and unit of analysis.

3.4. Source of Data and Data Collection Procedures

Data will be collected from top IT and other management groups of the universities in the selected universities using Likert scale questionnaires adapted from prior studies. The instrument will be pretested and pilot tested to check appropriateness after being adapted for this study. As the medium of communication is English for all universities, the survey instrument will be prepared in English and no need of translation to local languages.

3.5. Method of Data Analysis

The data collected will first be analyzed using descriptive analysis. Descriptive analysis is part of any research methods and will show the scenario on the ground. Next, correlation analysis will be tested to check the relationship between each independent variable the dependent variable. Finally, multiple regression analysis will be done using AMOS Software to check the effect of the independent variable (ITG performance) on the dependent variable (Organizational Success). Structural Equation Modeling (SEM) will be used to observe the effect of the independent and the moderating variables on the dependent variable at a time. The validity and reliability of the data will be ensured by using standardized instrument from prior studies and conducting Confirmatory Factor Analysis (CFA) to make sure that the instrument is usable in the Ethiopian context.

4. CONTRIBUTIONS OF THE STUDY

This study is expected to have the following significant contributions for various stakeholders. Primarily, it will have theoretical contributions to IS research by incorporating IT auditing in IT governance and using theories of Corporate governance for IS research. Secondly, it will have major academic contributions by incorporating IT audit and governance topics in the IS curricula. Thirdly, it will enable practitioners and policy makers make use of these models for proper practical use of IT for short term operational and long term strategic use of IT. Finally, it will serve as a base for other researchers in the areas of IT audit and governance replicating the same study, introducing new variables, investigating other types of organizations such as NGOs and the like.

5. LIMITATIONS OF THE STUDY

This study will target only public universities in Ethiopia. Private universities follow the same business models that banks and other institutions adopt and are excluded from this study. In addition, conceptually, the study primarily emphasizes on three major aspects of IT Governance. These are IT value delivery, IT risk governance and IT performance management. IT value delivery refers to the extent IT contributes to organizational goals and objectives to be measured in timely delivery of information, customer satisfaction and other deliverables as appropriate. IT risk governance on the other hand will emphasize on IT value preservation by mitigating various IT related risks as investigated by Parent and Reich (2009). IT performance management will help assess the value delivered out of IT investments and how risks are mitigated thereby relating the first two aspects of IT governance.

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Basic Digital Skills: Next Critical Skills Set towards a Resilient Nation

Michael Zimba[1], Misheck Nyirenda[2] and Patricia Khonje[3]
Department of Information and Communication Technology, Faculty of Science, Technology and Innovation, Mzuzu University, Mzuzu, Malawi.
[1]mgmzimba@gmail.com
[2]misheckvn@gmail.com
[3]patkhonje@yahoo.com

Abstract

The world is evolving fast in terms of digital technological advancements. Nevertheless, most Malawians still lack basic digital skills. This paper starts by defining basic digital skill, learning from different frameworks through strategic document review, then justifies why basic digital skills should be introduced early in basic education institutions and be considered on the same scale of importance as traditional literacy skills. The paper then advocates for early uptake and acceptance of basic digital skills as mandatory life skills in Malawi's basic education system and that the basic digital skills should be treated in the same level of necessity as traditional literacy skills. The paper further accentuates that the spectrum of digital skills has grown tremendously in recent years such that attaining competitively productive Information and Communication Technology (ICT) graduates requires the introduction of entry-level digital skills to be consigned further down on the Malawi national qualification framework to primary schools, adult literacy institutions and out-of-school training houses. This would, not only leave the masses of learners who drop from the education system with necessary basic digital skills to access digital information for their livelihood and lifelong learning, but also create opportunity for undergraduate university students to meaningfully engage emerging technologies. Lastly, the paper alludes that such restructuring of content would accord ICT graduates with modern skills that, not only matches the current and projected market demand of digital skills, but also adequately prepare the graduates to follow the cutting-edge of the fast-advancing digital skills continuum. This would entrench the necessary ICT-enabled resilience of Malawi as a nation.

Keywords: digital skills, qualification framework, emerging technologies, 4th industrial revolution

1 Introduction

All economies of the world experience the impact of and some are catalyzed by digital technologies. The benefits expected and accrued from these technologies, collectively referred to as digital dividends, have potential of strengthening the resilience of these economies. Digital technologies boost growth, expand opportunities and improve service delivery thereby adding value to gross output in the economies (WDR, 2016).
Digital technologies are restructuring the market place changing the patterns of production and consumption. Digital technology is becoming increasingly intertwined with everyday life: from schooling and education to political engagement and even financial and health management (Grand-Clement, 2017). Estimates for 2019 indicated that 4.1 billion people were using internet. Data flow had grown from 100GB per day in 1992 to 46600 GB per second in 2017. It is projected to grow further to 150, 700 GB per second by 2022 (WITSA, 2019). Due to the rapid growth of digital technologies, it is becoming increasingly difficult to live in contemporary society without using digital technologies as more and more day-to-day routine activities can be done with the support of digital technologies. Further, the implication of the big data and the increasing adoption of emerging technologies is that the world economy is transforming at a

rapid pace (WITSA, 2019). It follows, therefore, that those not able to access these technologies are at risk of being excluded from socio-economic provisions and opportunities in society (Devaux et al., 2017).

The aggregated impact of the digital technologies, however, is not evenly distributed. For digital technologies to benefit everyone and everywhere, it is required that we close in on the remaining digital divide, especially in internet access. Even then, greater digital adoption on its own would not be enough. To get the most out of the digital revolution, countries will need to work on the "analog complements" by strengthening regulations that ensure competition among businesses, adapting workers' skills to the demands of the new economy, and ensuring that institutions are accountable (WDR, 2016).

The legal and regulatory framework is the most critical aspect with respect to the activities associated with digital economy. The overall impact of the digital economy will be felt across all sectors if the (big) digital data is managed and analyzed efficiently (WBG, 2019). This can only be possible with leveraging of the emerging technologies such as Data science, Artificial intelligence, Machine learning, Deep learning, Internet of things, Blockchain and 5G network technologies. Furthermore, connectivity within the country and across countries is of prerequisite importance.

While nations are building the foundations of the digital economy, there is need to adopt a comprehensive ecosystem approach. The digital transformation must aim at digitally enabling every individual, business and government by 2030 (WDR, 2016). Demand-driven approach is necessary in defining the requisite elements of the digital economy. More importantly, the skills required in the digital economy need to be mapped against the existing supply of skills in labour force. Any existing gaps in digital skills should be addressed by appropriately aligning the skill development initiatives to the demands.

2 Economic and Digital Landscape of Malawi

Malawi is considered as a least developed country (LDC) by global classifications (WBG, 2019). The gross national income (GNI) per capita for Malawi is at US$380 and is less than the global average of US$11,599 (WBG, 2019). Malawi also scores low on the human assets index (HAI) at 52.5 which is less than both the average for LDCs at 53.1 and the average of developing countries at 76.4 (UN, 2018). The economic vulnerability index of Malawi at 47.1 is higher than the averages of both LDCs at 41.3 and developing countries at 34.7. These and more related indicators suggest that the economic landscape of Malawi is not really favourable for accruing meaningful dividends of a digital economy, unless Malawi strategically capitalizes on its bulging young population.

On network readiness index (NRI) Malawi is ranked 117th out of 121 (WITSA, 2019). NRI is one of the leading global indices on application and impact of ICT in economies around the world. The ICT sector forms an essential part of the digital infrastructure requirement to ensure availability of telecom, broadband, computers and software across the country that feed a digital economy. Malawi has one of the weakest connectivity infrastructures in the Southern Africa Development Community (SADC) region (SARUA, 2008). In order to counter digital divide and provide users with universal network coverage, Malawi needs to build an efficient digital infrastructure. This should immediately be followed by putting in place mechanisms for affordable access to internet.

Digital technology innovation ecosystem of Malawi is not only underdeveloped, but also highly fragmented. For a digital ecosystem to have impact, it needs to have a strong integration with different

actors of the economy. Nevertheless, there is significant contribution to the economy from the informal sectors (WBG, 2019). To adequately prepare the youth employed in informal sectors and those pursuing entrepreneurship, effective mapping of skills demands and corresponding training programs is critical. Incorporating digital literacy as an integral part of basic education curricula would allow for skill up-gradation to competitive national and global levels. We therefore advocate for early uptake and acceptance of basic digital skills as mandatory life skills in our (Malawi's) basic education system and that the basic digital skills should be treated in the same level of necessity as reading, writing, and numeracy. We believe that, apart from digital infrastructure and access to internet, the greatest challenge to reaping meaningful digital dividends lies in building relevant skills for a digital economy. For a digital economy to thrive, digital skills must also function together with other abilities such as strong literacy and numeracy skills, critical and innovative thinking, complex problem solving, an ability to collaborate, and socio-emotional skills in the connected economy and society.

3 (Basic) Digital skills

Before we proceed further, it is important to develop a common understanding of (basic) digital skills. The United Nations Educational, Scientific and Cultural Organization (UNESCO) defines digital skills as a range of the abilities to use digital devices, communication applications and network to access and manage information (UNSECO, 2018). *The entry-level (basic) digital skills to this range of skills are the basic functional skills required to use digital devices and online applications. They are considered as critical component of the new set of literacy skills in the digital era, in the same level as the traditional skills such as reading, writing and numeracy.*

The United Kingdom Digital Skills Taskforce (UKDST, 2014), single out *basic digital skills as skills needed to interact with digital technologies, and emphasizes that such skills are necessary life skills*.

The Organization for Economic Co-operation and Development (OECD, 2016), goes further than just defining digital skills. It categorizes the digital skills into: a) ICT specialists skills which are competencies to develop, operate and maintain ICT systems; b) Advanced users skills which are described as a set of skills for 'competent users of advanced, and often sector-specific, software tools'; and c) *Basic users skills which are for a group of users described as 'competent users of generic tools (e.g. office suites and internet-related tools such as browser and email clients) needed for the information society, e-government and working life'. ICTs for this user group are mainly used as a communicating tool*.

In Development Economics 'The Future Digital Skills Needs of the UK Economy' Report, (FDSN, 2013) digital skills are defined as 'the attributes that allow individuals and businesses both to use digital equipment and to access, create or share digital information via the internet and thereby benefit from opportunities in the modern economy'. The report sets out what it calls 'a functional hierarchy of these digital skills' as follows: a) Advanced digital skills which are skills linked to 'the creation and/or strategic exploitation of new digital applications, including more advanced programming and coding involved in the creation of new software'. Such skills also cover 'the strategic business skills needed to convert ideas into successful commercial projects and ventures'; b) Intermediate-level digital skills which are skills needed to implement and manage on a day-to-day basis the applications developed by those with advanced skills, but they may also provide contributions to the development of digital content, provision of system support and maintenance; and c) *Entry-level (basic) digital skills which are skills related to 'the use of digital*

applications designed, developed and promoted by other, involving for example searching for and/or the capturing and recording of digital data across a wide variety of business and public services, the administration of databases, the monitoring of data, contributing to the management of digital content'.

In defining digital skills for the UK economy, the Department of Business Innovation and Skills and the Department of Culture Media and Sports of United Kingdom (DBIS&DCMSUK, 2016) broadly categorize digital skills into: *a) Basic digital literacy skills (for empowering individuals) which are skills needed by every citizen to become 'digitally literate'. These are the skills needed to carry out basic functions such as using digital applications to communicate and carry out basic internet searches;* b) Digital skills for the general workforce (up-skilling for the digital economy) which include all skills belonging to Category a) plus skills needed in a workplace and generally linked to the use of applications developed by ICT specialists. While the digital skills needed by the workforce are likely to differ across sectors, there will be some minimum requirements linked to processing information that will be applicable across all sectors; c) Digital skills for ICT professions (digitally innovative and creative individuals, organizations and businesses) which include Categories a) and b), plus skills needed to work across the diverse ICT sector. They include digital skills linked to the development of new digital technologies, and new products and services. Such skills are needed if a nation is to compare favourably with other nations in relation to ICT investment and utilization.

Based on the strategic literature review of the various frameworks above, we affirm that much as digital skills form a continuum, *basic digital skills are fundamental entry-level functional skills required to make rudimentary use of digital devices and applications*. These skills can be seen as literacy life skills that are essential for being able to access and use digital devices/technologies and access digital information. These skills allow an individual to operate devices, to connect to the internet, to set up accounts and profiles, and to access information and resources. Basic skills are essential life skills in the same lenses as traditional literacy skills such as reading, writing and numeracy. It is therefore only proper that all such skills are appropriately placed on the qualification framework, to the basic education part of the education systems hierarchy. In our subsequent articles, we intend to develop a detailed matrix of the recommended basic digital skills, contextualized to Malawi's digital ecosystem. We will also discuss investment projections if Malawi nation were to opt for our proposition.

4 Rationale for placing basic digital skills training in the basic education sector

The (Malawi) National Education Sector Plan (NESP 2008 – 2017), gives both national and global definitions of basic education. The understanding at national level and within the Ministry of Education (MoE) is that basic education implies only primary education. However, NESP is quick to acknowledge that, globally, basic education is for the age range starting from 0 – 16 years old and it includes pre-school (Early Childhood Development), Primary education, adult literacy as well as out-of-school youth. Pre-School is for 5 years old and below. Primary education is for 6 – 13 years old and it has eight standards. Out-of-school youth education and adult literacy is for those aged 15 years and above; however, in practice out-of-school youth include children who could be under primary school but are not attaining primary education. In this paper, we opt for the global definition of basic education, particularly because it includes two important non-formal groups of the population, namely the adult literacy group and the out-of-school youth group. The two groups cover a large proportion of the Malawi's population.

We argue that mainstreaming basic digital skills training to the broader basic education sector as is defined in the global view, will widen the reach and enhance the impact of such training. For example, adult illiteracy in Malawi remains high, particularly among women and the poor. According to the 2005 Integrated Household Survey, only 64% of adults (15 years and above) were literate. The corresponding literacy rates for male adults and female adults were 76% and 52%, respectively. The link between literacy, development and poverty reduction is that literate people are able to access information pertaining to their development needs from a variety of sources. Literate people understand and easily follow instructions for performing various development activities. Including this non-formal group of people in the entrenchment of digital literacy will be critical for inclusive participation of citizenry in the digital economy.

In addition, the provision of non-formal basic education to out-of-school youth is relatively new in Malawi. In recent past, the provision was in partnership with the then Ministry of Youth Development and Sports and Non-Governmental Organizations (NGOs). The then Ministry of Education, Science and Technology was piloting the implementation of Complementary Basic Education (CBE) in four districts. Nevertheless, out-of-school youth education is essential as it aims at providing essential knowledge, skills and values to promote self-reliance, encourage lifelong learning and full participation in societal development, (NESP, 2008 – 2017). Out-of-school youth programmes target those who dropped out of primary school and those who have never attended school. Including these youths in the digital literacy initiative will be important for their participation in the digital economy.

Overall, the longest existing structure under basic education and within the entire education sector is primary education. Primary education is the sub-sector which affects the greatest number of people, and which is the basis for all other formal education sectors. Good primary education is valuable both for those who leave school at the end of primary, and for those who continue with their education. Only if the primary sector functions well can students gain the basic knowledge to progress to secondary and higher education institutions. World-wide, research shows that people who have good primary education are likely to be more productive in life than those who do not have, (WDR, 2016). Injecting basic digital skills at this level will be very strategic not only in freeing the higher levels of the education hierarchy to advance digital training, but also netting in a larger population of the youths who drop out on the way. For example, Education Sector Implementation Plan II (ESIPII, 2014 – 2018), reveals that only 47% of primary pupils from 2007 Standard 1 Cohort progressed to standard 6 within expected years. This is because each year between 3-15% of pupils drop out, depending on the standard, while between 14-15% failed to progress to the next standard and had to repeat the year. Standard 8 survival rate was 35% for girls and 41% for boys. An average survival rate of 38% thus suggests that an estimated 62% of Standard 1 entrants would not survive the primary school cycle within 8 years.

The situation becomes even more worrisome in post-primary levels. Access to public secondary schools is very restrictive as it is based on selection with a transition from primary to secondary education of just 32%. The tertiary gross enrolment rate is 0.4% – among the lowest in Africa. At 45 female students per 100,000 inhabitants, the rate is much lower than that for males which averages 86 students per 100,000 inhabitants (ESPII, 2014 – 2018).

Therefore, placing basic digital skills development in basic education system, would not only adequately equip our graduates with cutting-edge competitive skills, but also leave those who drop out on the way with necessary skills for lifelong learning and meaningfully competing for employment and entrepreneurial

opportunities. The (intellectual) demand accorded to acquiring of these basic skills scales comparably with that of contemporary traditional literacy skills that are already being offered in the basic education sector. The nation will only need to strategically invest in order to create conducive environment for the development of such critical life skills.

5 Conclusion

We have campaigned for early uptake and acceptance of basic digital skills as mandatory life skills in Malawi's basic education system and that such skills should be treated in the same level of necessity as reading, writing, and numeracy. Firstly, the pyramid structure of the Malawi education systems implies that the lower the level in the structure at which the training is introduced, the larger the proportion of the beneficiaries of the training. Secondly, we have accentuated that the fast growth of the spectrum of digital skills implies that if we were to have competitively productive ICT graduates, then basic digital skills needed to be consigned further down on to basic education institutions. This would create enough room for an undergraduate university student to meaningfully engage emerging technologies such as (Big) Data Science, Artificial intelligence, Machine learning, Deep learning, Block chain, 5G Networks, which define the 4th industrial revolution. Such restructuring of content would accord our ICT graduates with modern skills that not only would match the current and projected market demand of digital skills, but also adequately prepare the graduates to follow the front of the fast-advancing digital skills continuum. This would entrench the necessary ICT-enabled resilience of Malawi as a nation. In our subsequent articles, we will develop a detailed matrix of the recommended basic digital skills, contextualized to Malawi's digital ecosystem. We will also discuss investment projections if Malawi nation were to opt for our proposition.

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Smartphone Appropriation and Knowledge Retention in Technology-Mediated Learning

Daniel Dwomor
Department of Information Systems and Innovation, School of Technology, Ghana Institute of Management and Public Administration (GIMPA), Ghana
ddwomor@gimpa.edu.gh

Gamel O. Wiredu
Department of Information Systems and Innovation, School of Technology, Ghana Institute of Management and Public Administration (GIMPA), Ghana
gwiredu@gimpa.edu.gh

Abstract
Digitization of learning activities has introduced some notable improvements as well as some significant knowledge retention impairments. Extant theories of knowledge retention are dominated by instrumental and cognitive approaches. Relatively less attention has been paid to the smartphone appropriation which includes instrumental and cognitive approaches but transcends them. This research adopts the smartphone appropriation approach to model antecedents of knowledge retention in the context of technology-mediated learning. It synthesizes user-invited actions based on technology design, knowledge retention, looping, and unlearning. The data analysis and model testing primarily confirm smartphone appropriation in knowledge retention. Complexity of technology usage in itself does not cause an increase in cognitive load. Cognitive load increases because of the combination of smartphone appropriation and extraneous cognitive load. The proposed appropriation model of knowledge retention complements the extant ones. The theoretical contributions are discussed with their research and practical implications.

Keywords: appropriation, knowledge retention, technology-mediation, memory schemas, grafting

Introduction

In recent times, smartphone appropriation in the educational sector is on the increase especially because students are able to use mobile computers on-the-move to overcome and even leverage space and time barriers (Wiredu, 2014). This research seeks to model the relationship between smartphone appropriation and knowledge retention among students in their technology-mediated learning activities.

So far, the dynamics of knowledge retention have been encapsulated by two main approaches: instrumental and cognitive.

The instrumental approach overly focuses on the automation of learning processes and usage of novel digital technologies as antecedents to successful learning. Some notable knowledge retention theories in this research stream are replacement, amplification, and transformation (RAT) (Hughes, et al., 2005; Hughes, et al., 2006), substitution, augmentation, modification, and redefinition (SAMR) (Puentedura, 2010), and connectivism (Siemens, 2005). The cognitive approach predominantly focuses on the intense neural connections of memory schemas as antecedents to the successful learning process. Its notable theories include cognitive load (Chandler and Sweller, 1991), trial-and-error (Thorndike, 1988), and traditional blended learning (Behaviorism, Constructivism, and Cognitivism) (Ertmer & Newby, 1993).

While insights from both approaches are helpful, explanations stemming from them are quite simplistic and incomplete.

In the instrumental approach, smartphone appropriation is informed by automation and at the same time assumes a definite improvement in the outcomes of learning. For instance, the RAT model assesses technology integration in successful learning activities in three phases. Firstly, as a replacement of established learning processes to the same end. Secondly, as facilitating the increase in effectiveness, efficiency, and productivity. Finally, as reinventing learning in new and original ways. Technology in these

phases assumes a solutional role. This flow of thought is quite incongruent with the assumptions and outcomes of technology mediation in activities. This is because when technologies play a solutional role, positive or negative outcomes are not definite (Carr, 2003).

Similarly, the SAMR model calls for deeper integration of technology in all phases of the students' learning process – downplaying the role of the human characteristics in the modulation of the technology. This call presupposes a designers' praxis that intends positive outcomes only upon usage. However, this is not always the case. Technologies, as noticed by their 'platform' architectures, are customizable by users to take advantage of a continuum of praxis (Rahaman, 2017).

Similarly, connectivism combines technology and networks to proffer an understanding of knowledge retention in a digital age, acknowledging learning as a less individualistic activity. Knowledge is relative to multiple information sources, and technology acts as an interconnecting instrument. Thus, connectivism does not provide adequate insights about the learner's appropriation of the technology. The tools we adapt to learning activities rewire (define and shape) our minds (Siemens, 2005). As such, theories that acknowledge technology in learning activities must necessarily explain the effect of the learner-technology relationship.

In the cognitive approach, the antecedents of knowledge retention are primarily based on the presentation of information to be learned as well as the learner's efforts. For instance, the cognitive load theory (CLT) assumes knowledge retention to be improved following the reduction in cognitive load. This reduction, according to the CLT is made possible when information to be learned is structured in a format to lessen intrinsic and extraneous cognitive loads. However, it does not account for technology mediation and appropriation, leaving it in a passive or potential state.

Similarly, the trial-and-error theory assumes a highly motivated learner faced with a new and difficult problem, meandering across alternatives to arrive at an optimum solution. The theory indicates the retention of knowledge in the process. As the learner tries to find solutions, errors occur. The learner conflates the solutions and errors into a knowledge base and retains them to shape subsequent efforts. Like the CLT, the trial-and-error theory does not address technology mediation and appropriation issues. Thus, it does not account for the underlying social environment. The traditional blended learning theories (behaviorism, constructivism, and cognitivism) assume that a learner's effort is the only antecedent to knowledge retention. They promote the view of learning as occurring internally – only inside of a learner. Their explanations are limited as they fail to address learning that occurs outside of a learner. Knowledge acquisition in recent times does not follow a linear fashion as technology performs or supports some cognitive operations previously carried out by learners (Siemens, 2005).

The limitations of both approaches suggest the need to combine them synergistically to yield complementary knowledge of the interrelations between technology and cognition. These interrelations are captured by the proposed smartphone appropriation approach. Smartphone appropriation is neither solely instrumental nor solely cognitive; rather, it combines instrumentation and cognition to enable the study of their interrelations. Thus, this approach explains and predicts the relationship between technology convergence, proximity, connectivity, and modernity on the one hand, and connections in memory schemas on the other as antecedent to knowledge retention.

This paper identifies the specific determinants of knowledge retention among students who use and appropriate smartphone technology for learning. It deductively analyzes the factors that explain and predict students' reflective ability during technology-mediated learning. The hypotheses formulated tentatively explain and predict how and why the appropriation approach constitutes a complementary understanding of technology-mediated knowledge retention. Their tests confirm knowledge retention effects following the students' appropriation of smartphone technology.

The rest of the paper is organized as follows. First, a critical synthesis of the available literature and issues relating to knowledge retention in the context of smartphone appropriation is presented (Section 2). This is followed in Section 3 by a deductive analysis leading to the formulation of hypotheses and development of the conceptual model. Section 4 presents the methodology for this study. Sections 5 and 6 provide the results of data and hypotheses testing. The concluding section proffers some implications of the findings to researchers and practitioners.

Literature

This section presents a critical synthesis of the available literature and issues about smartphone appropriation and knowledge retention in building a coherent argument for undertaking this research. Smartphone appropriation includes its proximity, convergence, connectivity, mobility, and modernity. Knowledge retention includes a learner's cognitive ability as a precursor, looping as the stagnation of trained memory schemas in relative periods, and reflective ability.

Smartphone Appropriation

Even in the face of its unambiguous advantages, smartphone appropriation has been extensively linked to several negated consequences such as reduced attentional capabilities and distorted cognitions (Bianchi and Phillips, 2005; Billieux, 2012). The linkage is underpinned by the smartphone's change of status from an instrument supporting social exchanges to indubitably interfering with them (Nickerson et al., 2008). This interference is noticed in this study by problematizing smartphone's proximity, convergence, connectivity, and modernity.

The smartphone was birthed following the convergence of technological innovations in the communications and mobile computing industry (Conley & Christopher, 2010; Aker & Mbiti, 2010; Sarwar & Soomro, 2013). It relates with the user by a function of distance (Goldman, et al., 1998; Hashemi, et al., 2011) or proximity (Coren & Girgus, 1980; Boschma, 2005; Aguiléra et al., 2012; Cunningham & Werker, 2012). Elating the notion of proximity in smartphone appropriation is the concept of the multi-sided platform which dynamically supports the interplay between "distinct but interdependent groups of users" (Koh & Fichman, 2014, p. 977); see also Spagnoletti et al., (2015). Each user group is in essence a smartphone and an individual tightly coupled to the extent that the latter's representation by proxies of the former goes unnoticed (Oerlemans & Meeus, 2005). Whereas this tight coupling may be directly problematic in the face of issues such as addiction (Shambare, Rugimbana, & Zhowa, 2012), our attention is drawn towards the complex coordination processes between the users. The problematic perspective to this coordination is noticed by the erosion of structure between users in an inverse relationship with complexity (Oerlemans & Meeus, 2005). Structure indicates the formal protocols between users in a relationship. With the pervasiveness of smartphones, coordination among users is further complicated and as such, there is the impossibility to cooperate within specified structures – a rather important condition for knowledge retention.

Coordination among smartphone users is fueled by the trendy convergence of complementary technologies (Kallinikos, 2012). Convergence has had hardware and software technologies distinctively and cooperatively approaching unity (Lyytinen & Yoo, 2002; Bores, Saurina, & Torres, 2003; Calvo, 2019). This unity implies the seamless flow of data across the various software applications installed. Though this capability may seem advantageous, the problem arises with the smartphone technology performing cognitive operations previously carried out by users (Siemens, 2005).

Related to convergence is connectivity among subjects from remote sources and locations (Markus and Silver, 2008; Martin and Rizvi, 2014). Connectivity has introduced new forms of practices such as the replacement of face-to-face meetings with smartphone-based virtual forms (Dery et al., 2014). While such a technology-mediated practice may be fueled by some revelatory individual and collective benefits, there have been some flipside concerns with 'always-on' and information overload (Choi, 2016; Gao et al., 2018). For example, individuals may no longer able to disconnect from work as the challenge to achieve a state of connectivity while maintaining work efficiency and personal wellbeing increases (MacCormick et al., 2012). When this occurs, smartphone appropriation becomes excessive and uncontrollable, presenting a disservice to the user's mind as it has to deal with the overload.

On smartphone modernity, it is "a runaway engine of enormous power which … we can drive to some extent but which also threatens to rush out of our control …. The juggernaut crushes those who resist it, and while it sometimes seems to have a steady path, there are times when it veers away erratically in directions we cannot foresee ..." (Giddens, 1990a: 139). Modernity calls for the appropriation of smartphones as tokens of exchange media. During their use for exchange, people experience increased individualization and disconnection from traditional social structures (Beck, 1992; Jiang et al., 2018).

Knowledge Retention

"Forgetting is ubiquitous as the human memory is imperfect" (Qureshi et al., 2017: 126). Schemas or representations residing in human memory fade with time regardless of their nature, age, or background of the learner (Lindsey, Stroyer, Pashler, & Mozer, 2014; Kumar, 2017). However, a periodic review of these schemas is a requirement for a relatively long-term remembrance (Granito and Chernobilsky, 2012; Lindsey et al., 2014). Knowledge, according to the Schema Theory (Bern, 1983; Thornton, 2003) is systematized into units. This calls for assimilation by a function of size (Vitulic & Prosen, 2012). Tse *et al*. (2007) notice that this size is independent of every learner and is implicated by knowledge previously assimilated. This is where the concept of *grafting* comes in. A more informed learner would be able to assimilate new concepts or ideas easier and faster considering the availability of more memory interfaces for which new knowledge could be grafted (King, et al., 2019). In the heart of knowledge retention is an understanding of how knowledge is retained after grafting. In this study, how knowledge is retained is understood with the concept of a basic set-reset (SR) flip flop in replacement of anatomical approaches. The central hypothesis is that the mind has mental representations analogous to computer data structures. The introduction of flip flops to represent anatomical approaches to knowledge retention was adapted from Wolter Pieters' adoption of Niklas Laumann's system-theoretic notion of causal insulation to explain information security. We assign the term 'looping to the dynamics regarding how knowledge is retained in the mind.

Hypotheses Development

Cognitive Load Theory

CLT assumes a limited working memory and a virtually long-term memory (Chandler & Sweller, 1991). Working memory is limited and as we learn, it becomes overloaded which reduces the amount of information we can move to our long-term memory schemas. These schemas are mental structures that organize knowledge by how it is used. Cognitive load is placed on the very finite working memory and heavy load on this memory can have negative effects on task completion and retention. There are three types of cognitive load: intrinsic, extraneous, and germane.

The intrinsic is related to the complexity of the information the learner is paying attention to and processing. This is determined by the number of novel elements and the level of interactivity between the elements – given that working memory is limited to somewhere between 3-7 novel elements interacting at a time (Merrienboer & Sweller, 2005). The more elements a learner holds in long-term memory schemas, the easier the learning task will be because working memory is only limited when dealing with novel information.

The extraneous is essentially the load on the working memory that is completely unrelated to the learning task and can be considered as any distraction to the learning process. This load can be imposed by the poor design of information material. Extraneous load is anything included that does not directly contribute to the learning goal.

The germane is the mental processing effort of creating connections between existing knowledge and/or novel information. The germane load is the mental capacity that is directed at integrating the new information learned with existing knowledge. This load can be understood as an effort that contributes to the construction of schemas. A reduction in extraneous cognitive load (reducing unnecessary information not directly related to the learning process) and a reduction in intrinsic cognitive load (splitting the task and using informal previous knowledge) will result in more space or an increase in germane cognitive load.

The mental load is the aspect of cognitive load that originates from the interaction between task (intrinsic and extraneous) and subject (germane) characteristics. Related to mental load is mental effort which refers to the cognitive capacity that is actually allocated to accommodate the demands imposed by the task. Performance, also an aspect of cognitive load, can be defined in terms of the learner's achievements, such as the number of correct test items, a number of errors, and time on task (Paas, Tuovinen, Tabbers, & Gerven, 2003). In sum, CLT argues that there are many ways to utilize long-term memory storage and many ways to reduce cognitive load. This allows more space in working memory so learners can process more information and as a result, ease learning and increase performance.
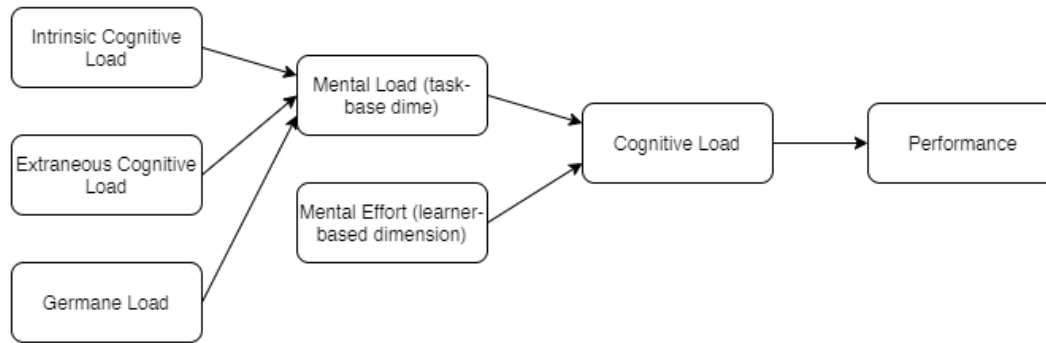
4

Figure 1 The Cognitive Load Theory. Source: Chandler and Sweller (1991)

Discussion and Hypotheses

Smartphone Appropriation & Mental Load

The dimensions of problematic smartphone appropriation point to several negated tendencies among individuals (Billieux, 2012). The CLT reasons this occurrence as a reduction in the germane load and an increase in the intrinsic and extraneous loads. Now, in a quest to improve the gratification and service the smartphone provides, updates and novel elements are constantly pushed to users. Even though the frequency of these updates is fairly low, the effects cannot be disregarded. The CLT assumes a working memory that is limited to somewhat three (3) to seven (7) novel elements interacting at the same time. There is no doubt that the novel elements a smartphone user is constantly exposed to surpass the limits assumed by the CLT – increasing the complexity the working memory has to deal with. These novel elements could be the application interfaces and variegated data churned following the platform participation of the smartphone device. Lest we forget, these novel elements should be also envisioned with regards to relational simultaneity and element interactivity. The CLT indicates this phenomenon as an increase in intrinsic cognitive load. We could hypothesize that:

H1: Smartphone appropriation increases intrinsic cognitive load.

With the novel elements mostly not directly related to the task undertaken by the smartphone user, there is a consumption of working memory needed for relevant tasks. Working memory required to deal with tasks in focus is apportioned to firstly deal with the grasping of novel technology features and any other characteristics posing a distraction to the processes of the working memory. The distraction posed could also include the tenets of modernity specifically the disembedded social systems and reflexive modern society. The CLT conceptualizes these distractions as an extraneous cognitive load. In this domain, the hypothesis below could be proposed:

H2: Smartphone appropriation increases extraneous load.

Still focusing on the presence of greater intrinsic and extraneous loads following smartphone appropriation, a significant reduction in germane load is noticed since there is less creation of connections between new information and existing information. First of all, the rate of exposure to novel elements is high and hence the 'reverberation' of these elements in the working memory is inconsistent to save in long-term memory. Since knowledge retention is enhanced with connections between novel information and existing schemas, the germane load is decreased in the event of 'less' long-term memory. Thus, we could hypothesize that:

H3: Smartphone appropriation decreases germane load.

Further inching on the relationship established aforehand about the intrinsic, extraneous, and germane cognitive loads, the CLT collectively conceptualizes them as mental load. The literature review presented insights about the potentially unlimited space in long term memory and the finite amount of space in working memory. In actuality, learning is made possible following the consolidation and reconsolidation of schemas from working memory to long term memory. But this presupposes that schema should primarily be available in working memory. The CLT highlights the inability of a learner to make available schemas in working memory as a result of an increased intrinsic, extraneous, and a decreased germane load. In

furtherance, the CLT assumes a posture to argue out the definacy of a decreased germane load following increased instances of intrinsic and extraneous cognitive loads. Also, increased intrinsic cognitive loads qualify as extraneous loads. To exemplify this reasoning, consider the sentences below:

➢ GIMPA lecturers are deeply thoughtful.
➢ GIMPA lecturers are the arrant embodiment of intellectual depth.

The two sentences presented above may carry the same meaning. The first sentence however relatively qualifies as an epitome of providing a reduced intrinsic cognitive load as compared to the second one. Inasmuch as both sentences carry the same meaning, the presentation of sentence two (2) goes ahead of providing an increased intrinsic cognitive load to providing an extraneous cognitive load. Simply, the presentation of sentence two (2) exposes conditions 'unrelated' to the understanding of the sentence and could be considered as a distraction to the understanding process. Thus, an increased intrinsic cognitive load could gravitate towards an increased extraneous cognitive load and could be relatively associated with mental load. Collectively, the following hypotheses could be proposed:

H4: Intrinsic cognitive load is positively associated with mental load.
H5: Extraneous cognitive load increases mental load.
H6: Germane load decreases mental load.

Having established the conditions with which an increase in mental load is inevitable, The CLT generally emphasizes the relatively low mental load to achieve higher cognitive ability. In other words, the CLT considers the possession of a higher knowledge retention ability as a reflection of a lower mental load. Since the smartphone is the center of attraction in this study, we could propose the hypothesis:

H7: Mental load decreases knowledge retention.

Grafting

As established in the previous section, smartphone appropriation increases mental load. The CLT notes mental load as an aspect of cognitive load that originates from the interaction between task (intrinsic and extraneous) and subject (germane) characteristics. The other aspect of cognitive load is considered by the CLT as mental effort. Now, the literature review revealed the unreality of knowledge assimilation in a mind's original pristine state – tabula rasa. Leaning on the concepts presented about the preservation of knowledge in the brain, immediately ingested schemas (knowledge stock) required the presence of a congruent permanent schema (knowledge scion) to be able to 'stick' before reverberation. The latter and former conceptions were in the literature review assigned to the terms looping and grafting respectively. The ability to graft, though dependent on the number of schemas present in the student's mind is still independent of every student. The CLT indicates this ability as mental effort. In the presence of a high mental load introduced by the smartphone appropriation, the mental effort of the student is required to accommodate or counterbalance the cognitive load. In an attempt to further justify this reasoning, we would hop on the *law of requisite variety* where variety should absorb variety. With the introduction of variety in mental load, a notable variety of mental resources is required. The CLT notices this variety of mental resources as mental effort. In this regard, this study posits the following hypotheses:

H8: Mental load is positively associated with cognitive load.
H9: Mental effort decreases cognitive load.

With the increase in cognitive load, there is bound to be some knowledge retention effects. The CLT reasons these effects as evident in terms of the students learning achievements such as the number of correct test items, number of errors, time on tasks, and ability to produce praxical evidence. On this basis, we could hypothesize that:

H10: Cognitive load is positively associated with knowledge retention effects.

Conceptual Model

Depicted below is the conceptual model of this study – illustrating the relationships between the constructs forming the proposed hypotheses.
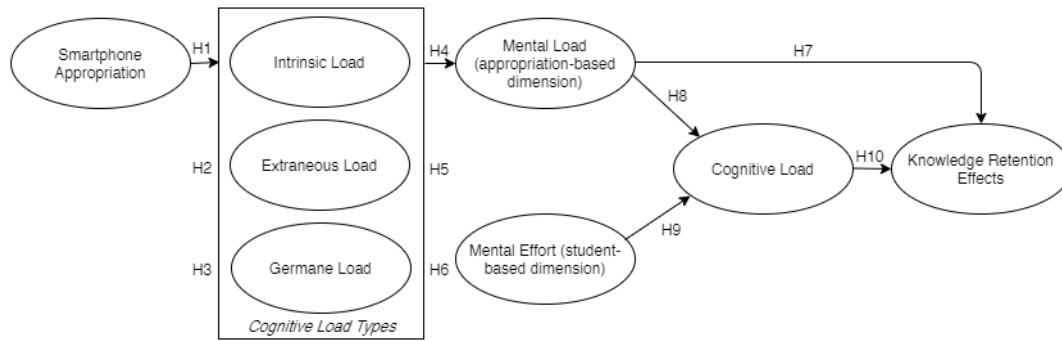
Figure 2 Conceptual Model

Method

Population, Sample, and Data Collection

This study considered a population of 1231 comprising all students under age 24 (as of March 2, 2020) from the various schools and sessions in the Ghana Institute of Management and Public Administration (GIMPA). This age range was necessitated as extant literature has found smartphone appropriation to be problematic among adolescents and young adults (Billieux, 2012). The population was restricted to students who double as Ghanaians ultimately because of their distinctiveness in socio-cultural practices, assumptions, and their definition of 'modernity'. Burdened with the task of ensuring our population was fairly aligned with our problem and objectives, we deliberately excluded certain students who doubled as faculty members or employees. This we believed could reduce some sort of bias in the process of finding a representative sample for our population and the data collection process at large.

To calculate the sample size for the study, we adopted Krejcie and Morgan's (1970) formula due to the simplicity and reliability in determining sample sizes. At a 95% confidence level with a degree of freedom one (1); Chi-square (χ^2) = 3.841 and margin of error (e) = 0.05. With the current population of 1231, the sample size = 242 students and the sample interval = 5. Now, we targeted the calculated sample by conducting an online survey in line with the difficulties posed by the coronavirus pandemic.

Measures

Just like the collection of any other commodity, the instrument used in data collection determines the quantity, type, nature, and/or kind of information gathered. In this regard, we adopted the use of a 7-point response set or Likert-type scale. These response sets ranged from 1 (strongly disagree) to 7 (strongly agree). There were no allocations made for respondents to present any other information. In other words, the questionnaire consists only of closed-ended questions. Even though these robust methods may still generate errors in measurement as the issue of 'response sets' holds regardless of the response set, we could, however, do less to offset this predicament. We hope our analysis with Structured Equation Models (SEMs) may correct such measurement errors. Now, ahead of developing our data collection instrument, the table below defines each of the constructs and presents the respective observable indicators used in the measurement.

Method

In this study, we adopted a covariance-based analysis, Structural Equation Modelling (SEM) using the R and R studio environment. The main reason is the suitability for modeling causal systems or 'systems' of relationships and also its appropriateness in instances where the research is concerned with indirect or mediated effects between variables. We firstly established a satisfactory measurement model for the latent constructs in our conceptual model using Confirmatory Factor Analysis (CFA). We bear cognizance to the fact that all measurements are made with some error – whether random or systematic. Now, CFA ensures the presentation of good measures for our variables by trying to decompose the error value from the measured variable. This process is aided by the presence of multiple indicators for each latent construct – canceling out the error variables and exposing the true score of the latent construct (Fornell & Larcker,

1981). Following the establishment of a good measurement model, we specified the relationship between the latent constructs by fitting regression paths. We then tested hypotheses and assessed model fit using Kline (2005) cut-off criteria.

Results

Overview of Respondents

Our online survey method garnered data from 362 respondents. 68.5% of the respondents representing 248 were aged 18-24; in line with our population and sample. We focused on the first 242 responses comprising 58.3% male and 41.7% female. To get more insights, we asked respondents about their level of education. In response, 207 representing 85.5% replied they were pursuing undergraduate degrees, 32 representing 13.2% and 3 representing 1.2% replied they were pursuing Diploma and Post Graduate Diploma respectively. Also, 85.5% (207) of respondents indicated they were unemployed and currently enjoying the care of parents and guardians whereas 14.5% (35) were employed. We finally asked respondents to indicate how long they have used the smartphone. In response, 59.1% indicated they had used the smartphone below six (6) years, 31% had used the smartphone above 6 years, 7.9% - below 3 years, and 1.7% - below a year.

Measurement Model Assessment

To ensure we have established a satisfactory measurement model for the latent constructs in our conceptual model, we performed a Confirmatory Factor Analysis (CFA) using R and R Studio. Table 2 below illustrates the results. First, the factor loadings of the measured variables were larger than 0.50 and Cronbach's alphas of the constructs all reached a level of significance. Thus, the constructs in this study met the minimum reliability requirement. The CFA found the model to provide a good fit (GFI=0.909, NFI=0.950, RMSEA=0.012, SRMR=0.026, TLI=0.998, CFI=0.997) with the dataset in accordance to recommended cut-off criteria (Kline, 2005). The criteria also indicate that Average Variance Extracted (AVE) and Composite Reliability (CR) values greater than 0.5 and 0.9 respectively are more accepted. As shown in Table 2 below, the AVE and CR values for all the latent constructs are greater than 0.5 and 0.9 respectively. Also, the squared root of AVE (bolded in Table 3 below) is larger than the inter-construct correlation values both row-wise and column-wise – in accordance to the Fornell and Larcker (1981) criterion.

Table 1 Measurement Model Statistics

Indicators	Factor Loadings	Cronbach's α	Squared Loadings	AVE	Errors	Σ Squared Loadings	Sum of Errors	CR
SA1	0.90	0.79	0.81	0.77	0.191	6.92	0.692	0.91
SA2	0.88		0.78		0.223			
SA3	0.85		0.72		0.278			
ICL1	0.95	0.91	0.89	0.84	0.106	3.36	0.321	0.91
ICL2	0.89		0.78		0.215			
ECL1	0.88	0.92	0.78	0.79	0.222	7.15	0.617	0.92
ECL2	0.90		0.80		0.197			
ECL3	0.90		0.80		0.198			
GCL1	0.91	0.90	0.82	0.82	0.18	3.30	0.352	0.90
GCL2	0.91		0.83		0.172			
ML1	0.92	0.72	0.85	0.79	0.146	7.14	0.618	0.92
ML2	0.87		0.76		0.24			
ML3	0.88		0.77		0.232			
ME1	0.93	0.70	0.86	0.78	0.143	28.17	1.303	0.96
ME2	0.88		0.78		0.223			
ME3	0.86		0.74		0.259			
ME4	0.88		0.77		0.228			
ME5	0.87		0.75		0.252			
ME6	0.90		0.80		0.198			
CL1	0.91	0.70	0.83	0.82	0.174	13.13	0.716	0.95
CL2	0.91		0.82		0.179			

CL3	0.91		0.84		0.164			
CL4	0.90		0.80		0.199			
KRE1	0.84	0.71	0.71	0.77	0.294	6.95	0.679	0.91
KRE2	0.87		0.76		0.245			
KRE3	0.93		0.86		0.14			

Table 2 Discriminant Validity Table in accordance to Fornell & Larcker (1981) Criterion

	SA	ICL	ECL	GCL	ML	ME	CL	KRE
SA	**0.877**							
ICL	0.588	**0.916**						
ECL	0.686	0.528	**0.891**					
GCL	0.719	0.507	0.558	**0.908**				
ML	0.731	0.753	0.730	0.685	**0.891**			
ME	0.305	0.447	0.276	0.423	0.539	**0.885**		
CL	0.325	0.478	0.459	0.462	0.663	0.791	**0.906**	
KRE	0.503	0.443	0.494	0.524	0.644	0.564	0.687	**0.879**

Structural Paths and Hypotheses Tests

After performing the Confirmatory Factor Analysis (CFA) to establish a satisfactory measurement model, we performed a structural equation analysis to ascertain the relationships between the latent constructs with regards to variance and covariance. Table 4 below illustrates the results. The analysis found the model to provide a good fit (GFI=0.878, NFI=0.932, RMSEA=0.034, SRMR=0.080, TLI=0.998, CFI=0.984) with the dataset in accordance to the recommended cut-off criteria (Kline, 2005). Table 4 below presents the standardized path coefficients (beta weights) as a representation of correlation or significance in the hypothesis similar to the p-value (Yu & Jieun, 2019). Generally, a beta weight greater than 0.8 represents a large significance or influence whereas between 0.5 and 0.8 represents a moderate significance or influence. Negative beta weights are not significant.

Table 3 Results of Hypotheses Testing

H	Relationship between constructs	Beta Weights (β)	Result
H1	Smartphone Appropriation (SA) → Intrinsic Cognitive Load (ICL)	-0.229	Rejected
H2	Smartphone Appropriation (SA) → Extraneous Cognitive Load (ECL)	0.684	Accepted
H3	Smartphone Appropriation (SA) → Germane Cognitive Load (GCL)	0.728	Accepted
H4	Intrinsic Cognitive Load (ICL) → Mental Load (ML)	-0.126	Rejected
H5	Extraneous Cognitive Load (ECL) → Mental Load (ML)	0.513	Accepted
H6	Germane Cognitive Load (GCL) → Mental Load (ML)	0.407	Accepted
H7	Mental Load (ML) → Knowledge Retention Effects (KRE)	0.356	Accepted
H8	Mental Load (ML) → Cognitive Load (CL)	0.349	Accepted
H9	Mental Effort (ME) → Cognitive Load (CL)	0.661	Accepted
H10	Cognitive Load (CL) → Knowledge Retention Effects (KRE)	0.465	Accepted

Discussion

Per the results, smartphone appropriation may not increase intrinsic cognitive load. Smartphone appropriation and intrinsic cognitive load had a negative standardized beta (β) regression weight between them. This could be interpreted as: an increase in smartphone appropriation seemingly leads to a lower intrinsic cognitive load. This result interestingly makes less theoretical sense but some practical sense. Theoretically, complexity is considered as the more novel elements the working memory has to deal with. Smartphone appropriation is not spared in this domain. The churning of variegated data and novel application interfaces and 'pop-ups' is all encapsulated in intrinsic cognitive load. Thus, more appropriation of the smartphone device should increase the intrinsic cognitive load. However, with regards to practicality, the more a person uses a smartphone, the more used they are to the device. They may need time to get used to the novel features and data. This time needed would be shortened by the constant appropriation of the smartphone. Implying, further usage may not necessarily require the need to accommodate novel elements in the working memory – as there may be no novel elements. In that domain, the hypothesis; an increase in

smartphone appropriation leads to a lower intrinsic cognitive load may hold true. Since this study upholds the theoretical rendition, we accept the rejected hypothesis. Also, the hypothesis 'intrinsic cognitive load is positively associated with mental load' was rejected. This hypothesis, though institutionalized by the Cognitive Load Theory (CLT) was rejected by our data. This could immediately imply that, in non-smartphone learning activities, intrinsic cognitive load is in positive association with mental load. Thus, with the smartphone appropriation in itself not increasing intrinsic cognitive load, as intrinsic cognitive load decreases, mental load increases. In a nutshell, smartphone appropriation has a positive influence on mental load.

Secondly, a keen look at the accepted hypotheses. Per the results, hypotheses (H2; H3; H5; H6; H7; H8; H9; H10) were accepted. Thus, about the dataset, the hypotheses formulated held. The hypotheses H7 and H8, however, had a relatively lower beta (β) weight of 0.356 and 0.349 respectively. Statistically, we may call for lower influence between the constructs in these hypotheses. However, it may not be the case in reality. For instance, a 10% reduction of risk following the protection granted by aspirin against cardiovascular disease may be seen as small. However, it is extremely important. Thus, in reality, the effect of mental load on knowledge retention as hypothesized in H8 may be significant.

Finally, our model exhibits moderate and substantial explanatory power in addressing the actual relationship between smartphone use and knowledge retention in successful learning activities. This inference is necessitated solely on a statistical basis. The r^2 values were 0.835 for smartphone appropriation, 0.053 for intrinsic cognitive load, 0.467 for extraneous cognitive load, 0.530 for germane cognitive load, 0.690 for mental load, 0.671 for cognitive load, and 0.512 for knowledge retention effects. Per Chin (1998), only r^2 values below 0.15 exhibit weak power with regards to explanation.

Conclusions

The model developed in this study added and subtracted factors or constructs from the Cognitive Load Theory (CLT) and Affordance Theory in Information System Discipline (ATISD). Though these additions and deletions in the simplistic sense suffice or qualify to be presented as theoretical contributions, we intend to focus on the epistemological ramifications. That is to say, how the changes made to the theories affected the accepted understanding of relationships between the constructs. Firstly, CLT. In smartphone appropriation in the learning activity domain, intrinsic cognitive load is not positively associated with the mental load. Also, excessive intrinsic cognitive load could result in extraneous cognitive load. Performance effects, as proffered by the CLT was particularly explicated as knowledge retention effects in this study. These contributions indicate that the CLT in its pristine state may not be able to better explain smartphone appropriation in successful learning activities.

Secondly, ATISD. Smartphone appropriation, as understood in this study subsumes affordances existent. Users appropriate the smartphone device on recognition of the affordance existent – from other entities as affordance recognition is mostly independent of the observer (Gibson, 1979). This is to say, Affordance Perception and Affordance Actualization in the ATISD could be identified as one major process rather than individual processes. The reduction into individual processes may however be helpful theoretically.

Implications for Researchers

Firstly, the young Information Systems (IS) researcher needs to be critical in adopting theories especially *mid-range* theories to explain phenomena. Mid-range theories are theories borrowed from IS reference disciplines (Grover & Lyytinen, 2015). For instance, Cognitive Load Theory (CLT) used in this study is a mid-range theory borrowed from Psychology. It proved insufficient in fully explaining the IS phenomena identified.

Secondly, the young researcher in an effort to bring research closer to reality and happenings around us needs to observe the opposite way to gap-spotting. Concerning the former, gap-spotting solely by looking at research contributions is not enough to contextualize research to current happenings. The researcher needs to be more observant of issues surrounding us in our daily activities and based on that, find a practical

problem and problematize it epistemologically. This form of reverse thinking and research would close the distance between most research and basic real-life occurrences.

Implications for Practitioners

The push to make legal the use of smartphones in Ghanaian senior high schools should not be solely informed by the technology providing solutions in teaching or learning. The smartphone affordance, among students, would be quickly recognized and appropriated accordingly. Noting the 'positive' and 'negative' smartphone affordances existent, and rise in mental load and knowledge retention effects following the appropriation, it would be better to enforce the current tradition – where smartphones are illegal to use in Senior High Schools. However, should there be any need to make smartphones legal, there would be a need for a psychological evaluation and assessment to ascertain the mental effort of the students. Other ways should be proposed to increase the mental efforts of the students before they are allowed to appropriate the smartphone in learning activities.

Limitations and Future Research Directions

With regards to practical methods, this study was plagued by the coronavirus pandemic – thereby making it barely impossible to administer questionnaires in the face-to-face mode and observe sample intervals even as the systematic random sampling technique was adopted. Also, the data analysis exposed adjusted goodness of fit indices (agfi) value of below the recommended 0.90 even as the goodness of fit indices (gfi) passed the recommended value. With the other fit indices passing the recommended values and modification indices set right, it was interesting to find out the agfi fell short of 0.001. Furthermore, there was a limitation to the choice of respondents. The study initially willed to use GIMPA students as respondents in the sample size. However, there is no objective proof that only GIMPA students within the specified age range responded even though the google forms link was shared with the WhatsApp groups and emails of these students. Now, some directions for future research. The structural equation model performed in this study revealed a fairly significant covariance between smartphone appropriation and mental effort. This is a non-directional path so no deductions were made. We suggest that future research could build on this and find the actual relationship between these two important variables. The measurement of smartphone appropriation is fairly prone to more questioning since affordances exists outside the basis of knowledge with regards to a particular observer. We recommend that future research in this domain finds a better and more objective measurement of this latent construct. This study could be subjected to replication in other settings such as smartphone appropriation and organizational performance to prove whether the findings would still hold true.

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Certificate-Less Searchable Encryption with a Refreshing Keyword Search

Kuma Ejeta, Minale Ashagrie
Addis Ababa University, Addis Ababa, Ethiopia
kumabek4@gmail.com
minale.ashagrie@aau.edu.et

Abstract

Public Key Encryptions with Keyword Search (PEKS) scheme had been hosted for keeping data security and privacy of outsourced data in a cloud environment. It is also used to provide search operations on encrypted data. Nevertheless, most of the existing PEKS schemes are disposed to key-escrow problems due to the private key of the target users are known by the Key Generating Center (KGC). To improve the key escrow issue in PEKS schemes, the Certificate-Less Public Key Encryptions with Keyword Search (CL-PEKS) scheme has been designed. Meanwhile, the existing CL-PEKS schemes do not consider refreshing keyword searches. Due to this, the cloud server can store search trapdoors for keywords used in the system and can launch keyword guessing attacks. In this research work, we proposed Certificate-Less Searchable Encryption with a Refreshing Keyword Search (CL-SERKS) scheme by attaching date information to the encrypted data and keyword. We demonstrated that our proposed scheme is secure against adaptively chosen keyword attacks against both types of adversaries, where one adversary is given the power to select a random public key as a replacement for the user's public key whereas another adversary is allowed to learn the system master key in the random oracle model under the Bilinear Diffie-Hellman problem assumption. We evaluated the performance of the proposed scheme in terms of both computational cost and communication cost. Experimental results show that the proposed CL-SERKS scheme has better computational cost during the key generation phase and testing phase than two related schemes. It also has lower communication costs than both related schemes.

1. Introduction

A cloud is an environment that allows ubiquitous resource sharing and data access to the client efficiently and effectively while reducing the up-front infrastructure costs (Kamara & Lauter, 2010). Apart from the enormous advantages of relying upon the cloud, it also poses a serious threat to the privacy and security of the client and the data that is outsourced. To keep the security of sensitive data, cryptographic encryption mechanisms are used to encrypt the user data before outsourcing it to the cloud (Bosch, 2014). However, how to process and search on the encrypted data becomes an intractable problem (Kamara & Lauter, 2010). To solve these problems, two methods were designed. The first method requires downloading the whole ciphertext data, decrypt it locally, and then search for the preferred results in the plaintext data. This approach would be impractical for most applications, because it requires downloading a large number of files and a lot of computational cost for decryption and (Bosch, 2014).

The second method is to let the server decrypt the data, runs the query on the server-side, and sends only the results back to the target user (Bosch, 2014). In this method, the target user sends the secret key to the cloud server to decrypt the query. This lets the server learn the plaintext being queried and hence makes encryption less useful. Instead, it is suitable to support the fullest possible search functionality on the server-side, without decrypting the data which is called searchable encryption (Bosch, 2014).

Searchable encryption can be classified into symmetric and asymmetric encryption. In 2000, Song et al (Song D X, 2000) first provided a practical searchable encryption technology, which became groundbreaking in the development of searchable encryption. The scheme is based on performing a sequential scan of the document without an index. Following Song et al (Song D X, 2000), Kamara et al (Kamara S, 2012) and Wang et al (Wang G. L., 2017) proposed searchable encryption schemes based on symmetric cryptography. In symmetric searchable encryption, the encryption and decryption parties need to exchange the key beforehand. To address this limitation, public-key searchable encryption (PEKS) was first proposed by Boneh et al. (D. Boneh, 2004). The PEKS doesn't require a prior key agreement

between the data owner and target user, the data owner generates ciphertext containing both encrypted documents and encrypted keywords using the target user's public key. Then, upload the ciphertext to the cloud service provider. When the target user needs to search the ciphertext for a certain keyword, it uses the secret key to generate the search trapdoor of the keyword and sends it to the cloud server. The server then runs a test operation to select the ciphertext file containing the target keyword and returns it to the target users.

On the other hand, certificate-less searchable encryption with keyword search (CL-SEKS) scheme is a public-key cryptosystem based on identity-based encryption (Zhou, 2020). It enables a cloud service provider to get the search trapdoor to identify ciphertext containing the target keyword without decrypting the ciphertext or knowing the target keyword. The private key in certificate-less public key encryption is no longer independently generated by the Public Key Generator (PKG), which is a device or program used to generate keys, but it is jointly generated by the PKG and the target users (Al-Riyami, 2003). Since certificate-less encryption based on the identity-based public-key cryptosystem was proposed by Al-Riyami et al (Al-Riyami, 2003), the scheme overcomes the problem of key escrow in identity-based searchable encryption, in which completely trusted private key generator can know all users' private keys. This is because it supports partial private key generation by the PKG for the target users and provides to generate their secret key, which is only known by the target user. Additionally, the scheme preserves the certificate-less advantages, it overcomes certificate management problems based on PKI encryption.

Despite the certificate-less schemes provides the above-mentioned advantages, there are remaining enormous issues and challenges. To perform certificate-less searchable encryption with keyword search, the data owner encrypts both keywords and data using the target users public key and identity (Yanguo, Jiangtao, Changgen, & Zuobin, 2014). Then, it sends the encrypted document to the cloud service provider. Then, the target user generates a search trapdoor using its complete private key and sends it to the cloud service provider to conduct a keyword search. Whenever the target user sends the trapdoors, the cloud service provider can store a trapdoor and it can use the trapdoors to search in ciphertexts (Baek, Safavi-Naini, & Susilo, 2008). By using the stored trapdoors for keywords used in the system, an adversary can launch a keyword guessing attack by checking all the encrypted documents and keywords without receiving the trapdoor from the receiver (J. Li, 2017). Even though there was a proposed certificate-less-based keyword searchable encryption (Yanguo, Jiangtao, Changgen, & Zuobin, 2014), (Baek, Safavi-Naini, & Susilo, 2008), (J. Li, 2017) the trapdoors for a keyword were never refreshed. For this reason, their schemes are vulnerable to keyword guessing attacks (KGA), which allows an attacker to recover the keyword from the trapdoor (Zhou, 2020). A keyword guessing attack is a type of attack in which the attacker can correctly guess the keyword encoded in a given keyword trapdoor (Bosch, 2014). This attacker can be, the outside keyword guessing attack (OKGA), a malicious entity that has no relationship with the cloud service provider. It is also called adversary type one and represented as A1. The inside keyword guessing attack (IKGA), which is usually launched by the cloud service provider or any other role inside the cloud service management (Zhou, 2020). It is also called adversary type two and represented as A2.

Following (D. Boneh, 2004) work, (Baek, Safavi-Naini, & Susilo, 2008) have been proposed a notion of keyword guessing attack and secure channel free PEKS scheme. The notion of KGA realizes the fact that the space of the keyword used is limited in practice. These are due to fact that the people usually select the keyword that is easy to remember. The notion of secure channel-free is the removal of secure channels for trapdoors between the data receiver and cloud service provider. Furthermore, there is no complete definition that captures secure channel-free PEKS schemes that are secure against chosen keyword attacks in their works. Later on, Chao et al (Wu T. M., 2017) demonstrated that their Certificate-less Designated Server Based Public Key Encryption with Keyword Search (CL-dPEKS) schemes (Baek, Safavi-Naini, & Susilo, 2008), (Wu, Meng, Chen, Liu, & Pan, 2016) suffered from KGA on ciphertext and trapdoor by the outside adversary. Chao et al (Wu T. M., 2017) also argued research works to design a new security model and secure scheme to overcome the known attacks.

To overcome the problem of the server storing trapdoor, Baek et al. (Baek, Safavi-Naini, & Susilo, 2008) and Bosch *et al*. (Bosch, 2014) suggested that "refreshing keyword will improve the vulnerability of KGA

on searchable encryption". Baek *et al*. (Baek, Safavi-Naini, & Susilo, 2008) argued that research works need to take on finding an efficient and convenient way to refresh frequently used keywords. The idea behind refreshing keyword search is to generate a trapdoor that is only valid in a specific time interval (Bosch, 2014) (Baek, Safavi-Naini, & Susilo, 2008). Considering the E-mail communication, the data sender defines the time interval for trapdoor generation by the data receiver. Every time the data receiver generates its trapdoor and search information from the cloud service provider, the trapdoor information is made to expire after the time defined by the data sender. Both Bosch *et al* (Bosch, 2014) and Baek et al (Baek, Safavi-Naini, & Susilo, 2008) suggested that searchable encryption with the refreshing keyword will improve the security of public encryption with keyword search. The literature shows that there is a gap in conducting research work in PEKS with a refreshing keyword and demonstrate its security.

Certificate-less searchable encryption with a refreshing keyword search can be defined as a public-key cryptosystem based on identity-based encryption and refreshing keyword search. The concept behind refreshing keyword search is to generate a trapdoor that is only valid in a specified time frame by the data sender. This helps to generate different trapdoors for the same keyword by attaching time information to the trapdoor indicating its validity. It also limits the time in which an adversary can launch KGA by captured trapdoors and is unable to distinguish active trapdoors from expired trapdoors. This research aims to design certificate-less searchable encryption with a refreshing keyword search CL-SERKS scheme. This needs to limit the duration of time the trapdoor remains active and to refresh keywords every time searching is conducted, by attaching time information to encrypted data and keywords.

1.1 Our contributions

In this paper, we first propose a CL-SERKS scheme and then prove its security in the random oracle model under the bilinear Diffie-Hellman problem assumption. The proposed CL-SERKS scheme refreshes the keyword by attaching time information to the encrypted keyword and the encrypted document. Similar to other certificate-less primitives, the proposed certificate-less keyword search scheme leverages the identity as the user's partial public key and eliminates the key escrow problem. We demonstrate that our scheme can resist adaptive chosen keyword attacks even in the presence of both two types of adversaries. Finally, the performance of the proposed scheme is evaluated in terms of computational and communication costs.

The rest of this paper is organized as follows. In Section 2, we discuss related work. In Section 3, we present some preliminaries, which give background information on concepts that are used to design the proposed scheme. In Section 4, we present the system model of the proposed scheme. Section 5 describes the proposed scheme, security model and security proof of the proposed scheme. In Section 6, we present the performance analysis of our proposed scheme. Finally, we conclude the paper in Section 7.

2. Related work

In this section, we discuss related work conducted in the field of certificate-less searchable encryption with keyword search (PEKS).

Peng et al (Yanguo, Jiangtao, Changgen, & Zuobin, 2014) introduced the concept of certificate-less public key encryption with keyword search, a key part of searchable encryption for both protecting data and providing operability of encrypted data. The authors' eliminated the problem of key escrow for the first time. They designed a certificate-less PEKS (CL_PEKS) scheme in an email system and constructed a secure channel-free scheme. The scheme only supports a single keyword search function. They proved its security under the bilinear Diffie–Hellman assumption. However, the scheme was later found out to be vulnerable to attacks involving a malicious key-generation-center and an offline keyword guessing attack (Wu, Meng, Chen, Liu, & Pan, 2016).

Mima et al (Ma, He, Kumar, Choo, & Chen, 2017) designed a certificate-less searchable public-key encryption with multiple keywords (SCF-MCLPEKS) scheme for IoT (Internet of Things). They demonstrated the security of the scheme in the random oracle model against both types of adversaries, where type I adversary one is given the power to select a random public key as a replacement for the user's public key and type II adversary two is capable to learn the master key. The performance of the

proposed scheme was evaluated in terms of communication and computational cost. Zheng et al. (Zheng, Li, & Azgin, 2015) integrate certificate-less cryptography with a keyword search on encrypted data. They presented a concrete construction and proved its security under the decisional linear assumption in the standard model.

Wu et al. (Wu, Meng, Chen, Liu, & Pan, 2016) proved that the certificate-less searchable public-key encryption scheme of Peng et al. (Yanguo, Jiangtao, Changgen, & Zuobin, 2014) cannot resist a malicious PKG attack and an offline keyword guessing attack. Therefore, the main contribution of the research work of (Wu, Meng, Chen, Liu, & Pan, 2016) was to address the vulnerability of the CL-PEKS schemes. Even though there was a proposed certificate-less-based keyword searchable encryption, the trapdoors for a keyword were never refreshed. For this reason, their schemes are vulnerable to KGA, which allows an attacker to recover the keyword from the trapdoor (Zhou, 2020). To reduce the vulnerability of certificate-less searchable encryption with keyword search to keyword guessing attacks, we propose a CL-SERKS scheme that resists KGA.

3. Preliminaries

3.1 Bilinear pairing

Let G_1 is an additive cyclic group and G_T is a multiplicative cyclic group having the same order q with G1, we build bilinear pairing e: $G_1 \times G_1 \rightarrow G_T$ is a map. This mapping satisfies the following properties.

1. Bi-linearity: $\forall a, b \in Zq^*$ and $\forall K, L \in G1$, $e(aK, bL) = e(bL, aK) = e(K, L)^{ab}$, where Z be a set of integers and a, b $\in Zq^*$ is a cyclic group of prime number.
2. Non-degenerate: there exists K, L $\in G_1$ so that $e(K, L) \neq 1 \in G_T$.
3. Computable: $\forall K, L \in G1$, there is an efficient algorithm to compute $e(K, L)$.

3.2 Bilinear Diffie-Hellman problem assumption

Let e: $G_1 \times G_1 \rightarrow G_T$ be a bilinear pairing. Suppose that we have a generator P of G_1 and some known points $P, aP, bP, cP \in G1$, where $a, b, c \in Zq^*$ are unknown numbers, the bilinear Diffie-Hellman (BDH) problem is to compute $e(P, P)^{abc} \in G_T$. It can be stated that BDH problems are intractable provided that any polynomial-time algorithm has a negligible advantage in computing BDH problems

$$(\Pr[(aP, bP, cP) = e(P, P)^{abc}]) \leq \varepsilon. \qquad (1)$$

4.System model

Next, we describe the system model of our proposed certificate-less searchable encryption with a refreshing keyword search scheme, which has four entities, namely: a cloud server, a data sender, a data receiver, and a key generation center (KGC).
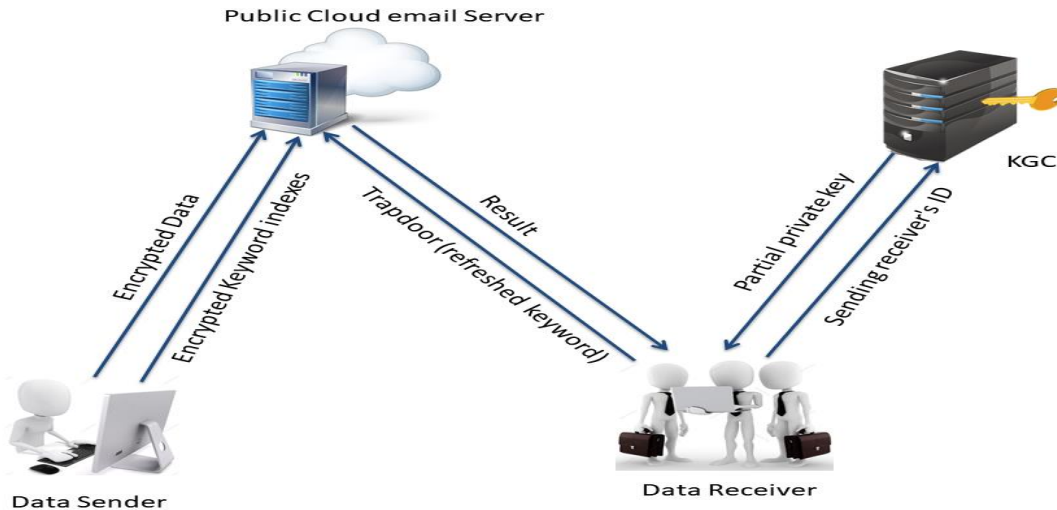

Figure 1 The CL-SERKS model

KGC is responsible for generating system keys.

Data sender uses the receiver's and server's public keys to encrypt the data and the index of keywords contained in the data. Once this has been performed, the data owner can store the encrypted data and encrypted keyword indexes in the cloud service provider.

Data receiver obtains his/her partial private key from the KGC and generates the trapdoor of keywords that he/she wants to search and sends it to the cloud server.

The cloud service provider is responsible for processing data, such as storing and searching data for a user.

5.Proposed scheme

In this section, we present the proposed CL-SERKS scheme, security model and security proof of the proposed scheme

5.1 Proposed CL-SERKS scheme

The CL-SERKS scheme consists of the following polynomial-time probabilistic algorithms:

Setup (k): suppose q is a large prime number, G is a group with order q. Let P denote a generator of G, and choose four different cryptographic hash functions $H1, H2, H3: \{0, 1\}^* \to G1$ and $H4: G_T \to \{0, 1\}^n \in Zq*$ where n is a fixed-length binary string, KGC performs the following steps

1. Select two cyclic groups G_1, G_T with the same order q and choose a bilinear pairing $e: G_1 \times G_1 \to G_T$
2. Choose a generator $P \in G_1$ and select a number $s \in Zq*$ randomly
3. Compute $P_{pub} = sP \in G_1$. Let s be the master key,
4. Publishes public parameter $prms = (k, G_1, G_T, q, P, P_{pub}, H1, H2, H3, H4)$ and keep master key s as secret. And moreover, the refresh keyword space $w = \{0, 1\}^* \in G_1$ and refreshed encrypted keyword space is $C_w = \{0, 1\}^n \in G_T$.

Extract partial private key (D_{ID}): KGC receives data user's digital identifier $ID \in \{0, 1\}^*$ as an input and computes $Q_{ID} = H1(ID)$. Then compute data user's partial private key $D_{ID} = sQ_{ID}$

Set secret value (X_{ID}): The data sender and data receiver input their identities $ID \in \{0, 1\}^*$, then the data user chooses $X_{ID} \in Zq*$ randomly as its secret value.

Set private key (SK_{ID}): The data user input X_{ID} and D_{ID}. Then compute $SK_{ID} = (X_{ID}, D_{ID})$

Set public key (PK_{ID}): Input public parameter and secret value X_{ID}, compute $PK_{ID} = X_{ID} P$

Encryption: Let $w = \{wi \mid 1 \leq i \leq n\}$ represent a set of refreshing keywords. In our case, a keyword is refreshed by the frequently used keyword by attaching date information to the encrypted document, for example, a keyword $w = w \| 24/02/2021$ represents a refreshing keyword where 24/02/2021 denotes "24 February 2021" and, owner of a data sends this refreshed keyword to the public cloud server. A data sender executes as follows to encrypt refresh keyword $wi \in W$ after obtaining public parameter $prms$, data user's public key PK_{ID} and data user's or receiver's identity ID as an input:

1. Compute $Q_{ID} = H1(ID)$
2. Choose a random number $ri \in Zq*$. Then perform $Ui = riP$.
3. Compute $Ti = e(ri(H2(w\|24/02/2021)), PK_{ID})e(riQ_{ID}, P_{Pub})e(ri(H3(w\|24/02/2021)), P)$
4. Perform: $Vi = H4(T_i)$ (2)

Final encrypted document or cipher-text is the output and given by: $C = \{C1, C2 \ldots\}$

Where $Ci = (Ui, Vi)$ (3)

Trapdoor: In this step, the algorithm receives public parameter $prms$, a refreshing keyword and, the data user's Secret Key SK_{ID} as an input. The trapdoor is performed by the data user as:

$T_w = X_{ID}(H2(w\|24/02/2021)) + D_{ID}$ (4)

Test: At the test stage, the public cloud server receives public parameter $pmrs$, refreshed keyword w's trapdoor $Tw's$ and refreshed keyword encrypted document Cw as input and Performs:

$Vi = H4(e(T_w + (H3(24/02/2021)), Ui))$ (5)

If the equation (5) is correct, the output is "1"; else outputs "0". Assume that $w = wi$, wherein $i \in \{1, 2 \ldots n\}$, we show that the CL-SERKS scheme fulfills the computational consistency as given below:

$H4(e(T_w + (H3(wi\|24/02/2021)), Ui))$

$=H4\ (e(X_{ID}(H2\ (w\|24/02/2021)) + D_{ID} + (H3\ (w\|24/02/2021)), riP)).$

$= H4\ (e(X_{ID}(H2\ (w\|24/02/2021)), riP)\ e(D_{ID}, riP)\ e(H3\ (w\|24/02/2021), riP))$

$= H4\ (e(ri(H2\ (w\|24/02/2021)), X_{ID}P)\ e(sQ_{ID}, riP)\ e(H3\ (w\|24/02/2021), riP))$

$=H4\ (e\ (ri\ (H2\ (wi\ \|24/02/2021)), PK_{ID})\ (riQ_{ID}, Ppub)\ (ri\ (H3\ (wi\ \|24/02/2021)), P))$

$=Vi$ (6)

5.2 Security model

In the certificate-less cryptosystem, there are two types of adversaries. Type I adversary one, is denoted as A1 and has no master key but can replace anyone's public key, and type II adversary two, is denoted as A2 and holds the master key but cannot replace anyone's public key. The security model is defined through two games played between adversaries and a challenger ch. The challenger is an honest data user in the cryptosystem which implies that it works following a predefined cryptographic framework. An adversary is in charge of communicating to the system by placing a query to the oracle, that orders a challenger to answer the queries to either of the adversary type *A*1 or adversary type *A*2 and its main goal is to break the proposed system. The CL-SERKS scheme mainly considered ciphertext indistinguishability and trapdoor indistinguishability.

5.2.1 Ciphertext indistinguishability

Ciphertext indistinguishability (IND-CKA) ensures that the ciphertext reveals no information about the underlying keyword to the cloud server. The CL-SERKS is said IND-CKA secure if the advantage of winning in the following *Game 1* and *Game 2* are negligible

Game 1: In this game, we set the semi-trusted cloud service provider as the adversary A1.

Setup: The challenger performs the setup algorithm so that it obtains public parameter $prms$ and master key s. Then it sends public parameter $prms$ to the A1 and keeps master key s privately.

*Phase 1: A*1 performs the oracle query as follows:

*Hash query: A*1 can query all hash algorithms and get corresponding answers.

Partial private key extract query: Given identity ID_i, Ch executes partial private key extract algorithm to acquire D_{ID} send to A1.

Request public key query: Given identity ID_i, Ch produces PK_{ID} and sends it to the A1.

*Substitute public key query: A*1 can select a random value in place of the data user's or receiver's PK.

Private key extract query: Given identity ID_i, ch calculates the corresponding private SK_{ID} to A1.

Trapdoor query: Given the keyword w_i with identity ID_i, ch calculates the corresponding trapdoor T_{Wi} to the A1.

Challenge: A1 chooses keyword (w_0, w_1) and identity ID_i, which is expected to challenge, ch randomly chooses a $\in \{0,1\}$ and runs encryption algorithm to produce a target keyword cipher-text C_a to A1.

*Phase 2: A*1 can issue the polynomial query like phase 1, but cannot make a trapdoor query with $wi \neq (w_0, w_1)$.

Guess: Finally, the A1 yields $b' \in \{0, 1\}$. We say adversary A1 wins this game if $b' = b$.

Game 2: In this game, we set the semi-trusted KGC as the adversary A2.

Setup: ch run the setup algorithm is executed to get public parameter $prms$ and master keys s of the system. Then adversary A2 receives public parameter $prms$ and master key s from Ch.

*Phase 1: A*2 can adaptively issue public key queries, extract private key queries, perform hash queries, and trapdoor queries.

Challenges: A2 chooses keywords $(w_0\ w_1)$ and identity ID_i to challenge, Ch selects a $\in \{0,1\}$ uniformly and runs an encryption algorithm to produce C_a to A2.

*Phase 2: A*2 can issue the polynomial query like phase 1, but cannot make a trapdoor query with $wi \neq (w_0, w_1)$.

Guess: The A2 yields $b' \in \{0, 1\}$. We say adversary A2 win this game if $b' = b$.

5.2.2 Trapdoor Indistinguishability

Trapdoor indistinguishability guarantees that the cloud service provider cannot obtain any information about the keyword from a given trapdoor.

If A1 and *A*2 advantage of winning in the following games *Game 3* and *Game 4* are negligible respectively, we can say that the scheme is satisfied with the trapdoor indistinguishable under the adaptive chosen keyword attack.

Game 3: The interaction between A1 and the Ch is as follows:

Similar to Game 1, we set the semi-trusted cloud server as the adversary A1.

Setup: The ch outputs the system parameters by running the setup algorithm, where ch does not know the master key s.

*Phase 1: A*1 can adaptively issue query as follow:

*Hash query: A*1 can query the hash algorithm and get the corresponding answer.

Extract partial private key query: Given the identity ID_i, the ch calculates the corresponding partial private key to the *A*1.

Public-Key query: Given the identity ID_i, the ch calculates the corresponding public key to the *A*1.

*Replace public key query: A*1 can replace the public using his choice.

Encryption query: Given the keyword wi with identity ID_i, ch calculates the corresponding ciphertext Ci = (T_i, V_i) to *A*1.

*Challenges: A*1 chooses keywords (w_0, w_1) and challenges identity ID_i to challenge. The ch randomly selects $b \in \{0,1\}$ and returns trapdoor search T_w to *A*1 by running the trapdoor algorithm.

*Phase 2: A*1 can issue the polynomial query like phase 1, but cannot make CL-SERKS query with $wi \neq$ ($w0$, $w1$).

*Guess: A*1 outputs $b' \in \{0, 1\}$.

Game 4: The interaction between *A*2 and ch is as follows.

Setup: The ch outputs the public parameters and the master keys by running the setup algorithm.

*Phase 1: A*2 can adaptively issue a hash query, public key query, private key query and encryption query.

*Challenges: A*2 chooses keywords (w_0, w_1) and identity ID_i to challenge. Then challenge randomly selects $b \in \{0,1\}$ and returns trapdoor search T_W by running trapdoor algorithm to *A*2.

*Phase 2: A*2 can issue the polynomial query like phase 1, but cannot make encryption query with $wi \neq$ (w_0, w_1).

*Guess: A*2 outputs $b' \in \{0, 1\}$.

5.3 Security proof

Theorem 1: The CL-SERKS scheme proposed in this research is secure semantically in random oracles against adaptive chosen keyword attacks if the problem of BDH is not breakable to resolve in probabilistic polynomial time.

Lemma 1: Supposing the existence of probabilistic polynomial-time adversary *A*1 in Game 1, which can attack the proposed CL-SERKS scheme with $\boldsymbol{\varepsilon}$ i.e. a very minimum chance of breaking the proposed scheme. We can build ch (i.e. challenger algorithm) to compute the problem BDH with the advantage ε. Suppose $q\text{H1}$, $q\text{H4}$, $q\text{Trap}$, $q\text{Epart}$ and $q\text{Epriv}$ represent the numbers of $H1$ query, $H4$ query, trapdoor query, partial private key extract query and private key extract query respectively. The challenger algorithm will be built to compute the problem of BDH with the advantage:

$$\varepsilon' \geq \frac{\varepsilon}{q\text{H1}q\text{H4}} \left(1 - \frac{1}{q\text{H1}}\right)^{q\text{Epart} + q\text{Epriv} + q\text{Trap}} \tag{7}$$

Ch simulates challenger and replies to all the queries from adversary *A*1 in such a way that it uses the *A*1 to compute the problem.

Proof: Following Lemma 1, it is necessary to show that our framework is secure. Hence, a BDH problem difficult to solve chosen, and it is reduced to the security of our system. Ch inputs a BDH problem be the instance of (P, aP, bP, cP), the goal is to challenge A1 to compute $e(P, P)^{abc}$.

Setup: The Ch algorithm is provided with two groups G_1 and G_T of equal order q, the generator P of G_1 and a bilinear map e: $G_1 \times G_1 \rightarrow G_T$, an algorithm Ch additional select four hash functions: $H1$, $H2$, $H3$:$\{0, 1\}^* \rightarrow G_1$ and $H4$: $G_T \rightarrow \{0,1\}^n \in Zq_*$, n denotes a binary string of fixed length. For instance, challenger set $P_{pub} = aP \in G_1$ for unknown value $a \in Zq_*$ and picks $IDi \in \{0, 1\}^*$ randomly as a digital identifier challenge. Then the Ch packages the parameters as *prms* (k, G_1, G_T, q, P, P_{pub}, $H1$, $H2$, $H3$, $H4$)

and returns public parameter *prms* to the adversary $A1$ where $H1$, $H2$, $H3$, $H4$ are random oracles organized by the challenger algorithm. Then, the ch algorithm is required to provide the responses because of an $A1$ queries without understanding a master secret key s and execute the following queries in phase one.

H1 Query: A ch maintains a hash list called *H1-List* containing tuples *(IDi, δi, Q_{IDi})* that is empty initially. When the identity *IDi* is submitted for query, the challenger checks whether *IDi* is already in the hash list *H1-List*. If the algorithm challenger ch does find *IDi* already in the tuple *(IDi, δi, Q_{IDi})* in *H1-List* then the challenger algorithm produces Q_{IDi} and sends to $A1$. If *IDi = IDI*, the challenger chooses an arbitrary number $σi \in Z_q^*$ and calculates $Q_{IDi} = σibP$. Otherwise, chooses an arbitrary number $σi \in Z_q^*$ and calculates $Q_{IDi} = σiP$. Finally, the ch adds *(IDi, σi, Q_{IDi})* to *H1-List* and output Q_{IDi} to $A1$.

H2 Query: A ch maintains a list *H2-List* with tuples *(w_i, δi, H2 (w_i))* that are empty initially. When adversary $A1$ asks a $H2$ query for sets of keywords w_i, a ch replies as follows and tests to check whether w_i, is already reserved in the *H2-List*. If $H2 (w_i)$ is already in a tuple *(w_i, δi, H2 (w_i))* in *H2-List*, then the ch returns the corresponding $H2(w_i)$ to adversary $A1$. Otherwise, the ch chooses an arbitrary number $δi \in Z_q^*$ and calculates $H2 (w_i) = δiP$. Later, outputs $H2 (w_i)$ and ch update *(w_i, δi, H2 (w_i))* to *H2-List* and send $H2 (w_i)$ to $A1$.

H3 Query: The ch maintains a hash list *H3-List* with the tuples *(w_i, $α_i$, H3 (w_i))* that is empty initially. When $A1$ asks a $H2$ query for sets of keywords w_i, a ch checks whether it is already in the *H3-List*. If this query has been asked challenger yields the record $H3 (w_i)$ and submits to $A1$. Otherwise, ch chooses an arbitrary number $α_i \in Z_q^*$ and calculates or computes $H3(w_i) = α_iP$. Finally, the ch returns $H3 (w_i)$ to $A1$ and adds *(w_i, $α_i$, H3 (w_i))* to the *H3-List*.

H4 Query: The ch maintains the hash list *H4-List* containing tuples *(T_i, V_i)* that is empty initially. When $A1$ makes hash a $H4$ query with $T_i \in G_T$, ch answers and tests if T_i is already stored in the *H4-List*. If T_i is in the tuple *(T_i, V_i)* then yields V_i and returns to $A1$. Otherwise, ch chooses an arbitrary number $V_i = \{0, 1\}$. Finally, the challenger *(T_i, V_i)* is added to the *H4-List* and sends V_i to $A1$.

Partial private key extract query: The ch maintains a list of partial private keys referred to as *PPK-List* containing tuples *(IDi, Q_{IDi}, $_i$)*. When $A1$ queries for extraction of the private partial key query of *IDi* from $A1$, the Ch performs or replies as follows: A partial private key list, returns to D_{IDi} as a response to $A1$, if there exists is a tuple containing the form of *(IDi, Q_{IDi}, $_{IDi}$)*. Otherwise, if *IDi ≠ IDI* query the $H1$ hash *List* for a tuple form *(IDi, σi, D_{IDi})*. The ch calculates $D_{IDi} = σiP_{Pub} = σiaP$, adds *(IDi, Q_{IDi}, D_{IDi})* into the private partial key list *(PPKList)* and returns to the back D_{IDi} as a response to $A1$. If *IDi = IDI*, challenger aborts.

Request public key query: The ch maintains a public key list *PK-List* containing tuples *(IDi, X_i, PK_{IDi})*. When $A1$ asks for the public key query of identity *IDi*, a ch answers as follows: If public key identity PK_{IDi} exits in the tuple form *(ID, x_i, PK_{IDi})* in the public key list, the ch sends PK_{IDi} as a response to $A1$. Else, select a random number $x_i \in Z_q^*$, calculate $PK_{IDi} = X_iP$, adds *(IDi, x_i, PK_{IDi})* into the *PK-List* and returns PK_{IDi} to $A1$.

Replace public key query: $A1$ can substitute a data user's public keys with new random values.

Extract private key query: In this phase, it takes identity *IDi* as an input and the ch maintains tuples of a private key list form *(IDi, x_i, D_{IDi})* that exists in private key extraction query list *SK-List*. After getting a private key extraction query *(IDi)*, ch answers as follows:

If a tuple exists *(IDi, x_i, D_{IDi})* on the private key list, returns to back *(x_i, D_{IDi})* to $A1$.

Else, *IDi ≠ IDI* executes public key request algorithm S to obtain a tuple *(IDi, x_i, PK_{IDi})* and also run partial private key extraction algorithm to obtain a tuple *(ID_i, Q_{IDi}, D_{IDi})*, modify to the private key list *(IDi, x_i, D_{IDi})* and returns *(x_i, D_{IDi})* as a response to $A1$.

If *IDi = IDI*, the ch aborts.

Trapdoor query: When $A1$ requests trapdoor query on refresh sets of keywords w_i for an identity *IDi*, the Ch replies as follows: If *IDi = IDI*, the ch aborts. Else, recovers *(IDi, x_i, PK_{IDi})* from public key list *PK-List*, retrieves *(IDi, Q_{IDi}, D_{IDi})* from *PPK-List* and recovers refreshed keyword *(w_i, δi, H2 (w_i))* from

hash list $H2$ *List* and calculates $Tw_i = X_{ID}H2\,(wi) + D_{ID_i}$. Finally, the ch returns the trapdoor Tw_i of the keyword w_i to $A1$.

Challenge: If $A1$ issues a challenge that phase one is over, select $ID*, \in \{0,1\}$ with public key PK_{ID*} and two different keyword sets $w0, w1$, where $w0 \neq w1$, $|w0| = |w1|$ and not requested by $A1$ in phase one, then ch executes as below: If $IDi* \neq IDI$ then Ch aborts. If $IDi = IDI$, ch selects a $\in \{0, 1\}$ randomly, and picks two arbitrary numbers that include $r \in Zq*$ and $V = \{0, 1\}n$.

Finally ch submits $C* = (rcP, V)$ to adversary $A1$. If $C_a = (rcP, V)$ is a meaningful cipher-text, then it is calculated as follows:

$V = H4\,((\delta P, xiP)^{rc}\,(\sigma ibP, aP)^{rc}\,(aP, P)^{rc})$

$= H4\,((P, P)^{\delta xi\,rc}\,(P, P)^{\sigma iab\,rc}\,(P, P)^{arc})$

$= H4\,((P, P)^{rc\,(\delta xi+\sigma)}\,(P, P)^{\sigma iab\,rc})$ \hfill (8)

More queries: $A1$ can execute or perform additional trapdoor queries on keyword sets wi where $w_0 \neq w_1$ and $wi \neq w1$, challenge responds as above. Additionally, an algorithm ch answers to $A1$ in a similar way as phase one under the restrictions defined below:

$A1$ is not able to query private key queries set of keywords on the challenge identity $IDi*$.

$A1$ is not able to place a partial private key extraction query on the challenge identity $IDi*$ if the public key of the challenge identity $IDi*$ was substituted before the challenge phase.

$A1$ is not able to put a trapdoor query on $(Tw_0, IDi*)$ or trapdoor query on $(Tw_1, IDi*)$ without the challenge phase.

Guess: Lastly, $A1$ yields $b' \in \{0, 1\}$ as its guess. In this case, ch can select a pair (Tw, Vi) arbitrarily from the hash list $H4$ *List* and $e(P, P)^{abc}$ can be calculated as follows:

Lastly, $A1$ yields $b' \in \{0, 1\}$ as its guess. In this case, ch can select a pair (T_i, V_i) arbitrarily from the H4-List and $e(P, P)$ can be calculated as follows:

$e(P, P)^{abc} = (T/e(P,P)^{rc(\delta xi+\alpha))}\dfrac{1}{r\sigma i}$

$= (e(P,P)^{rc(\delta xi+\alpha)}\,e(P,P)^{abrc\sigma i}/e(P,P)^{rc\delta xi+\sigma i})\,\dfrac{1}{r\sigma i}$

$= e(P, P)^{abc}$ \hfill (9)

6.Performance evaluation

We provide performance evaluations of our proposed certificate-less searchable encryption with a refreshing keyword search system with some existing research works such as Peng et al. (Yanguo, Jiangtao, Changgen, & Zuobin, 2014) and Mima et al. (Ma, He, Kumar, Choo, & Chen, 2017) in terms of computational time and security property.

6.1 Computation cost

The notations and the executing times used in the evaluation are defined in Table 1. The evaluation was performed on a personal computer (Dell with an i5-4460S 2.90GHz processor,4G bytes memory and Windows 8 operating system) using the MIRACL library (ltd., 2016).

Table 1 *Notations and execution times (ms)*

Notations	Description	Times(ms)
T_{sm}	a scalar multiplication execution time	2.165
T_{bp}	a bilinear pairing execution time	5.427
T_H	a Hash-to-point execution time	5.493
T_h	a general hash function execution time	0.007
T_{pa}	a point addition execution time	0.013

Table 2 shows the computational cost for Peng et al's. (Yanguo, Jiangtao, Changgen, & Zuobin, 2014) , Mima et al's. (Ma, He, Kumar, Choo, & Chen, 2017) scheme, and our proposed scheme.

Table 2 *Comparison of computational costs*

Comparison criteria	Peng et al. (Yanguo, Jiangtao, Changgen, & Zuobin, 2014)	Mima et al. (Ma, He, Kumar, Choo, & Chen, 2017)	Our proposed scheme
keyGen	$2T_H + 8T_{sm}$ =28.306	$2T_H + 4T_{sm}$ =19.646	$T_H + 3T_{sm}$ =11.988
Encryption	$3T_H + 2T_h + 5T_{sm} + 3T_{bp}$=43.599	$3T_H + T_h + 4T_{sm} + 3T_{bp} + T_{pa}$=41.433	$2T_H + T_h + 4T_{sm} + 3 \ T_{pb}$ =35.927
Trapdoor	$T_H + T_h + 3T_{sm}$ =11.995	$T_H + T_{sm} + T_{pa}$ =7.671	$T_H + T_{sm} + T_{pa}$=7.7
Test	$T_h + T_{sm} + 2T_{pa} + T_{bp}$=7.625	$2_{TH} + T_h + T_{sm} + 2T_{pa} + T_{bp}$=18.611	$T_H + \ + T_h + T_{sm} + T_{pa} + T_{pb}$=13.105

The computational cost of our proposed CL-SERKS scheme is lower than the Peng et al. (Yanguo, Jiangtao, Changgen, & Zuobin, 2014) and Mima et al. (Ma, He, Kumar, Choo, & Chen, 2017) scheme's as shown in table 2 and figure 2 except in test phase execution time is higher than Peng et al. (Yanguo, Jiangtao, Changgen, & Zuobin, 2014) scheme despite our proposed scheme provides refreshing keyword search.

6.2 Communication cost
We let |G1| denote the bit-size of a point in Group G

$|\mathbb{Z}q|$ denote the bit-size of a number in $\mathbb{Z}_q$

|PK| denote the bit-size of PK

|C| denote the bit-size of cipher-text

|T| denote the bit size of the trapdoor respectively. Table 3 shows the comparison of communication cost schemes in Peng et al. (Yanguo, Jiangtao, Changgen, & Zuobin, 2014), Mima et al. (Ma, He, Kumar, Choo, & Chen, 2017) and the proposed scheme.

Table 3 *Comparison of communication cost*

Comparison criteria	Peng et al. (Yanguo, Jiangtao, Changgen, & Zuobin, 2014)	Mima et al. (Ma, He, Kumar, Choo, & Chen, 2017)	Our proposed scheme

Size of PK	4|G1|	2|G1|	|G1|
Size of CT	|G1| + |$\mathbb{Z}q$|	|G1	+ |$\mathbb{Z}q$|	|G1	+ |$\mathbb{Z}q$|
Size of TD	3|G1|	|G1|	|G1|

It is also observed that the overall communication cost of the proposed system is less than both schemes in Peng et al. (Yanguo, Jiangtao, Changgen, & Zuobin, 2014) and Mima et al. (Ma, He, Kumar, Choo, & Chen, 2017) .

6.3 Security property

Table 4 *Comparison of security properties*

Comparison criteria	Peng et al. (Yanguo, Jiangtao, Changgen, & Zuobin, 2014)scheme	Mima et al. (Ma, He, Kumar, Choo, & Chen, 2017) scheme	Our proposed scheme
Certificate management problem	Yes	Yes	Yes
Key escrow problem	Yes	Yes	Yes
Refreshing keyword	No	No	Yes
Trapdoor security	No	No	Yes

Yes: denotes that the system meets the security requirements.
No: denotes that the system does not meets the security requirements

7. Conclusion

In this research, we proposed the CL-SERKS scheme. The proposed CL-SERKS scheme overcomes the issue of the server storing trapdoor for keywords in the system when the user performs a keyword search by his trapdoor on the cloud server that occurs in existing PEKS. This is achieved by attaching time date information to the encrypted data and keyword. It primarily improves the security of the outsourced data by reducing the chance for the cloud to guess the full keyword information that enables to access the ciphertext. We also prove that the designed scheme is secure against adaptive chosen keyword attacks in the random oracle model under bilinear Diffie-Hellman (BDH) problem assumption. The performance of the proposed CL-SERKS method is also provided and the results are compared with some of the existing schemes in terms of the computational and communication cost. An interesting open problem is to design CL-SERKS considering advanced search functions such as conjunctive, disjunctive, boolean and fuzzy keywords search over a real-world e-mail dataset.

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Fintech Use, Digital Divide and Financial Inclusion

Solomon Odei-Appiah, Gamel Wiredu and Joseph Adjei

School of Technology, Ghana Institute of Management and Public Administration (GIMPA), Accra, Ghana.

sodei-appiah@gimpa.edu.gh

gwiredu@gimpa.edu.gh

jadjei@gimpa.edu.gh

Abstract
FinTech innovations enable the provision of financial services to many unbanked across the world by increasing access. The key role of FinTech to drive financial inclusion however suffers significant impediments including the digital divide. Nevertheless, there is paucity of elaborate theories on financial inclusion while extant literature on FinTech only identify factors that drive its acceptance and use with little attention to inhibitors such as the digital divide. Employing the unified theory of acceptance and use of technology (UTAUT2) and the model of digital inequality, this study investigates the impact of FinTech usage on financial inclusion amidst the digital divide. A structural equation modelling technique is applied to data collected from 282 respondents in a survey. The findings confirm the influence of performance expectancy and facilitating conditions on behavioural intentions as well as a positive influence of FinTech use on financial inclusion. The results also show that digital divide measured with access, resource and force moderate the use of FinTech. Significant theoretical contributions are made by the study and practical and policy implications are offered for deepening financial inclusion.

Keywords: FinTech; financial inclusion; digital divide; digital inequality; UTAUT2.

1.0 Introduction
Financial technology (FinTech) is an emerging and evolving innovation that provides and facilitates financial services through various mobile and computing devices, the Internet, and payment cards (Arner et al., 2015; Hinson et al., 2019; Manyika et al., 2016). Such payment system innovation amplified by the increasing digitalization in various aspects of society, and the changing consumer behavior that is outpacing the rate of innovation in traditional financial services. The transformational capabilities of FinTech innovation is disrupting the existing business structures, changing how individuals and organizations acquire products and services (Philippon, 2019). Thus, FinTech is increasingly being perceived as an incipient participatory tool in the financial inclusion agenda (Makina, 2019; Zetzsche et al., 2019).

The important role of FinTech in financial inclusion aspects of the United Nations' Sustainable Development Goals (SDGs) cannot be over emphasized. Zetzsche and colleagues (2019) assert that, by providing payment services, insurance services, long-term (project and firm) financing, and savings/investment products, FinTech could indeed contribute directly and indirectly to attainment of a number of the 17 SDGs. The importance of financial inclusion to achieving the SDGs has led to numerous studies and interesting findings. Nevertheless, there is paucity of elaborate theories on financial inclusion (Prabhakar, 2019). Moreover the few extant theories are not only inadequate and limited in explaining financial inclusion (Besley et al., 2020; Kumar, 2011), but are also ineffective for testing financial inclusion constructs in empirical modeling and critical discourse (Ozili, 2020).

There exist significant impediments that mitigate FinTech's contributions towards sustainable financial inclusion. Notable among such inhibitions are the digital divide and socio-economic status variances (Demirgüç-Kunt et al., 2017; French and Baduqui, 2019; Hinson et al., 2019). Though many studies on

FinTech identify several factors that drive its acceptance and use, those that incorporate inhibitors such as the effect of the digital divide is scarce (Al-Ajlouni & Al-Hakim, 2018; Hinson et al., 2019).

This study investigates the role of FinTech use in deepening financial inclusion in light of the digital divide by addressing the following questions; how does FinTech use impact financial inclusion?; how does the digital divide influence the use of FinTech, and what is the relationship between FinTech use and financial inclusion while being moderated by the digital divide? The unified theory of acceptance and use of technology (UTAUT2) will be used as a theoretical support for this study.

The remaining part of the work is in the following order. Sections 2.1 and 2.2 present the literature review on financial inclusion, the use of FinTech and the digital divide. Subsequently, we introduce the theoretical foundation and provide overviews of UTAUT2 and the digital inequality model in sections 2.3 and 2.4 respectively. The paper continues with the research model and hypotheses in section 3, methodology description at 4, analysis and results at 5, discussions and conclusion at 6 and 7 respectively.

2.0 Literature Review and Theoretical Foundation

2.1 Financial Inclusion, FinTech Use and the Digital Divide
According to the United Nations Development Programme, (2019), Financial inclusion is the ability of the broad society to have access to and use varieties of financial services which are provided appropriately and responsibly in an environment well regulated. Since FinTech is a rapidly evolving field, there is not much consensus on the best definition for the innovation. However, existing definitions provides a good perspective. For the purpose of this study, the definitions of Jagtiani & Lemieux, (2017) and that of the Financial Stability Board, (2017) will be adopted. FinTech in this study therefore denotes a variety of technology-enabled business models, processes, applications or products for providing financial services effectively (Financial Stability Board, 2017; Jagtiani & Lemieux, 2017).

The contribution of FinTech use to financial inclusion is threatened in many ways and the digital divide is a marked one (French & Baduqui, 2019; Hinson et al., 2019). The uneven access to and use of ICTs across geographies and demographics is the condition referred to as the digital divide (Otioma et al., 2019). Although ICT innovations provide economic and social life transformations, there are disparities in the access and use of these digital opportunities among populations. To the Organisation for Economic Cooperation and Development (OECD, 2001), the digital divide is "the gap between individuals, households, businesses and geographic areas at different socio-economic levels with regard to both their opportunities to access ICTs and to use the Internet for a wide variety of activities."

Many studies indicate that adoption and use of FinTech is hindered by inadequate electrical or communications infrastructure and the lack of other resources in rural areas of most Sub-Saharan African countries (Adaba et al., 2019; Adetutu et al., 2019). Given the relative invisibility of digital infrastructures, its consequential exclusion of aspects of the population stands a great chance of going unnoticed. It is therefore imperative and critical that despite the touted potentials of FinTech use in many studies to deepen financial inclusion, how this feat can be achieved in light of the digital divide needs to be examined.

2.2 Prior Studies on FinTech and Financial Inclusion
Previous studies (for example, Chuang et al., 2016; Hu et al., 2019; Jünger & Mietzner, 2020) reveal that trust is very influential on FinTech's acceptance and use. Reliability, transparency, user innovativeness and financial literacy (Hu et al., 2019; Jünger and Mietzner, 2020) as well as perceived usefulness and perceived ease of use (Chuang et al., 2016), have also shown significant influence on intention to adopt and use FinTech. Friedline et al., (2019) report that early adopters of FinTech are usually younger individuals who are tech-savvy, have higher income and are urban, and customers who are younger and wealthier are the greatest users of Fintech services. This is contrary to the claim by many literatures that FinTech use can influence growth among the underprivileged and financially underserved.

It therefore begs the question of how the use of FinTech can deepen financial inclusion especially among the unbanked people. Many studies on FinTech identify several factors that drive its use. Nonetheless, studies that incorporate inhibitors such as the effect of the digital divide are scarce in the FinTech nascent literature. Understanding adoption and use drivers is vital, however given that inhibitors are capable of preventing an innovation from being adopted and its use discontinued possibly leading to its ultimate extinction, it underscores the importance of understanding effects of inhibitors. Thus to provide a broader understanding, a study incorporating the effects of both drivers and inhibitors is necessary.

With regards to theories on financial inclusion, concerns have been raised about the marked lack of synergy between the academic and policy literatures (Prabhakar, 2019). It can be observed that elaborate theories on financial inclusion are scarce in both literatures. Extant financial inclusion theories (for example Kumar, 2011; Besley et al., 2020) provide important insights on different aspects of financial inclusion. However, aside not being empirical, they are quite limited in explaining the intricacies of financial inclusion. This is reiterated by Ozili, (2020) who refers to existing theories on financial inclusion as being mainly practical descriptions which do not directly address how their relative effectiveness could be tested and the financial inclusion constructs empirically modelled and used for critical discourse. To address this gap, the study employs the unified theory of acceptance and use of technology (UTAUT) as a theoretical lens to ascertain the impact of FinTech usage on financial inclusion amidst the digital divide.

2.3 Unified Theory of Acceptance and Use of Technology

To understand the acceptance and use of technology, (Venkatesh et al., 2003) developed the unified acceptance and use of technology (UTAUT). By combining eight prominent models from the literature on user acceptance, the theory was developed by synthesizing constructs from these models. The UTAUT model gradually attracted attention of researchers when it appeared and has been since used in exploring user acceptance of even Fintech related services such as mobile banking (Yu, 2012). The theory has also been applied and tested on several other technologies both for individual and organizational use (Baptista and Oliveira, 2015). Due to some limitations to UTAUT despite its high explanatory power, it had to be extended and adapted to the consumer context thereby developing UTAUT2 with three additional constructs namely price value, hedonic motivation and habit (Fig. 1).

2.4 Integrated Model of Digital Inequality

An integrated model was developed by Yu et al., (2018) to provide a more thorough understanding of the digital divide and its complexities. The conceptualizations, measurements and determinants of the digital divide had been addressed by scholars from the perspectives of different domains such as information science, library, communications, education, and many more. This had resulted in the digital divide literature consisting of disparate and divergent definitional approaches, research questions and prescriptions to that single phenomenon (Helbig et al., 2009; Hohlfeld et al., 2008). In responding to calls for applicable measures and integrative theories, the problem of fragmented constructs for the digital divide was seemingly addressed by Yu et al. (2018) when they identified from literature access, resource and force as the three major determinants. Therefore, when conceptualizing the digital divide, access, resource and force form the key substrates, hence their use for this study.

3. Research Model and Hypotheses

The unified theory of acceptance and use of technology (UTAUT2) is combined with moderators from the integrated model of digital inequality as the study's theoretical foundation (Fig. 1). The most complete model to predict information technology acceptance and use was considered to be UTAUT (Martins et al., 2014) until the appearance of UTAUT2. Comparably, UTAUT2 provides a more substantial improvement than its predecessor (Venkatesh et al., 2012) hence its use in this work. Given that the digital divide affects the way people use information systems, moderators from the integrated model of digital inequality are also adopted in the study as illustrated in figure 2.

3.1 Performance Expectancy (PE)
Performance expectancy refers to the benefits that users believe the use of a technology will yield in the performance of their daily activities (Venkatesh et al., 2012). It is hypothesized that:

H1. Performance expectancy (PE) influences users' behavioural intention (BI) to use FinTech.
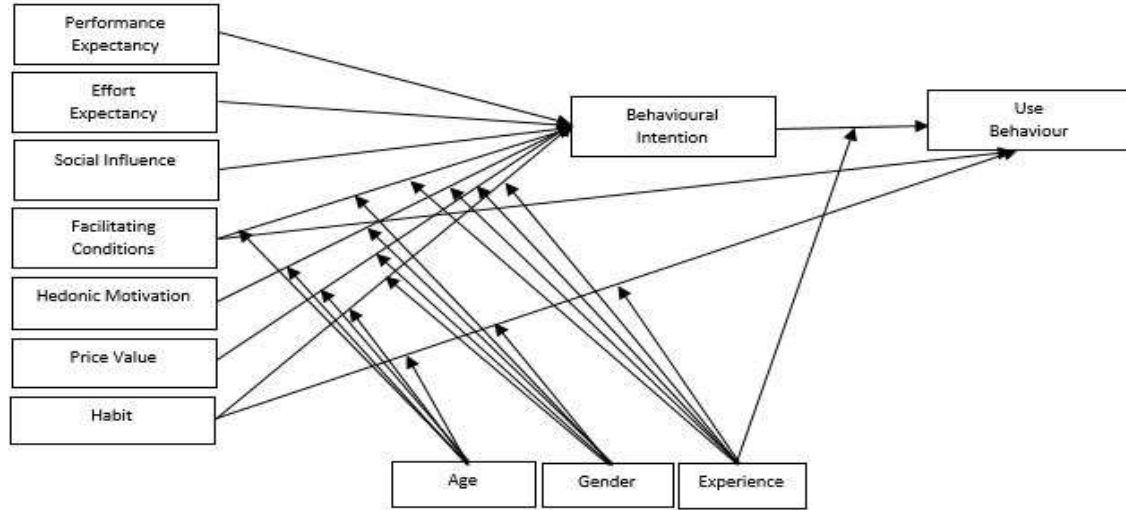
Figure 1: Unified theory of acceptance and use of technology (UTAUT2) model

3.2 Effort Expectancy (EE)
Effort expectancy describes the ease with which a technology can be used (Venkatesh et al., 2012). It is hypothesized that:

H2. Effort expectancy (PE) influences users' behavioural intention (BI) to use FinTech.

3.3 Social Influence (SI)
Social influence denotes how users consider that friends and family members as well as other important personalities expect them to use a technology (Venkatesh et al., 2012). It is hypothesized that:

H3. Social influence (SI) affects users' behavioural intention (BI) to use FinTech.

3.4 Facilitating Conditions (FC)
Facilitating conditions describe people's belief that the existence of technical infrastructures and related help will aid their use of a technology when necessary (Venkatesh et al., 2012). It is hypothesized that:

H4a. Facilitating Conditions (FC) influence users' behavioural intention (BI) to use FinTech

H4b. Facilitating Conditions (FC) influence users' actual use behaviour (UB) of FinTech

3.5 Hedonic Motivation (HM)
Hedonic motivation denotes how pleasurable it is to use a technology (Venkatesh et al., 2012). It is hypothesized that:

H5. Hedonic motivation (HM) influences users' behavioural intention (BI) to use FinTech.

3.6 Price Value (PV)
Price value describes how a user perceives cost-benefit in monetary terms of using a technology (Venkatesh et al., 2012). It is therefore hypothesized that:
H6. Price value (PV) influences users' behavioural intention (BI) to use FinTech.

3.7 Habit (HB)

The repetition of behaviour results in the automatic performance of certain actions that lead to the formation of habits (Baudier et al., 2020; Venkatesh et al., (2012). It is hypothesized that:

*H7a. Habit (HB) influences users' behavioural intention (BI) to use FinTech.*

H7b. Habit (HB) influences users' actual use behaviour (UB) of FinTech.
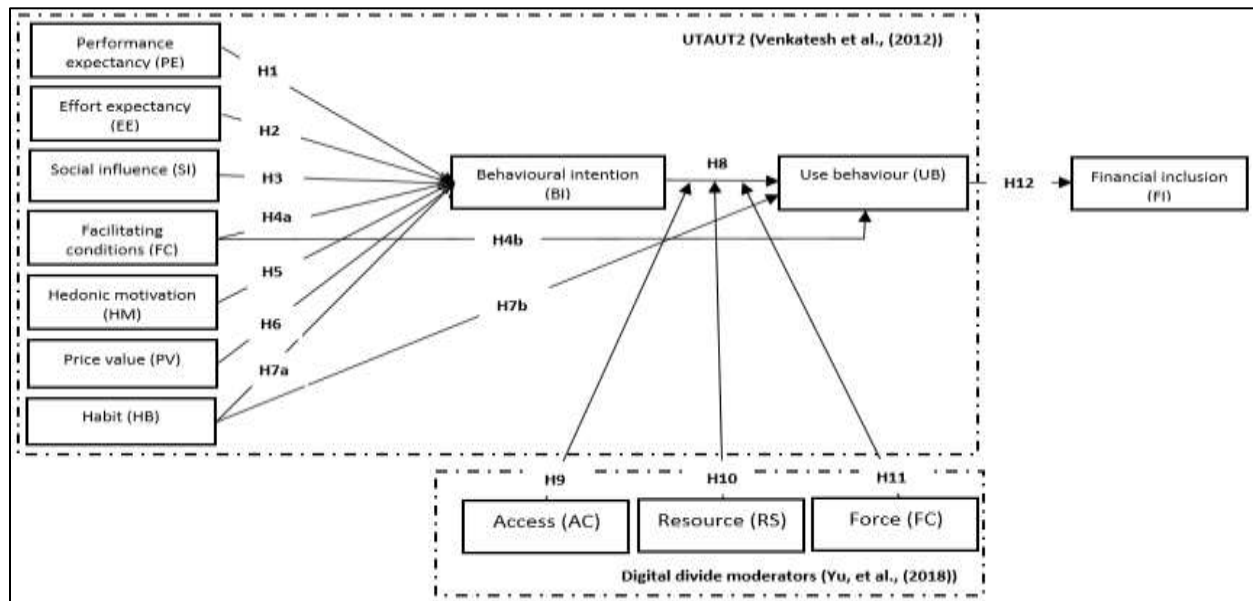
Figure 2: Research model

3.8 Behavioural Intention (BI)

Ajzen, (2002) describes behavioural intention as the likelihood for a particular behaviour to be performed by a user. Many studies such as Chopdar et al., (2018) and Macedo, (2017) have established that there is a relationship between behavioural intention and actual use which is positive. It is thus hypothesized that:

H8. Behavioural intention (BI) influences actual use behaviour (UB) of FinTech users.

3.9 Access (AC)

Access, which is one of the three determinants of the digital divide, refers to the overall ability of an individual to readily make use of particular ICTs in a given scenario (Thompson and Afzal, 2011; van Dijk, 2005). It is therefore hypothesized that:

H9. Access (AC) moderates behavioural intention (BI) on use behaviour (UB), in such a way that the relationship will be stronger among individuals with more access.

3.10 Resource (RS)

Resource as a theoretical construct describes the money, infrastructure, social networks, materials and other apparatuses in stock or supply which users can draw upon to realize their general use of technology. Lots of studies assert that resources such as household income have great impact on ICT use (Fuchs, 2009). Hence, it is hypothesized that:

H10. Resource (RS) moderates behavioural intention (BI) on use behaviour (UB), in such a way that the relationship will be stronger among individuals with more resources.

3.11 Forces (FC)

According to Hsieh et al., (2008) forces describe systems, stakeholder groups or institutions with the capabilities for perpetuating or alleviating digital inequality. These forces can be said to determine or be detrimental to the use of ICT (Yu et al., 2018). It is therefore hypothesized that:

H11. Forces (FC) moderate behavioural intention (BI) on use behaviour (UB), in such a way that the relationship will be stronger among individuals with stronger forces.

3.12 Financial Inclusion (FI)

Financial inclusion is the ability of the broad society to have access to and use varieties of financial services importantly among the population left out from the traditional financial system (Baber, 2019; Queralt et al., 2017). Many studies assert that the use of FinTech will positively impact financial inclusion (Demirgüç-Kunt et al., 2017; Jagtiani and Lemieux, 2017; Zetzsche et al., 2019). It is therefore hypothesized that:

H12. The use behaviour (UB) of FinTech users has an impact on financial inclusion (FI).

4.0 Research Methodology

The research context was Ghana, a middle-income country in Africa which was the first in sub- Sahara and happens to be among the first countries on the continent to launch a cellular network (Coffie et al., 2020). Ghana is among the emerging fast-growing mobile money markets in sub-Saharan Africa (Senyo and Osabutey, 2020). Currently in Ghana, the FinTech market has dominance shared by mobile-based, online payments, card-based and other blockchain related third-party applications. Nevertheless, a large section of the Ghanaian population still remain unbanked and mostly use cash for performing transactions. The choice of Ghana as the research context is based on these unique characteristics of her population.

Data collection targeted the adult population that have the experience of using any FinTech product such as payments, mobile/online banking, crowdfunding, insurance, loans, etc. A questionnaire in English was developed with reference to the research model. Most of the items were adapted from previous studies except those of financial inclusion which were developed from the literature. Venkatesh et al., (2003) and Venkatesh et al., (2012) were the sources from which the UTAUT2 construct items and scales were adapted while those of the digital divide moderators were from Yu et al., (2018).

5.0 Data Analysis and Results

The data analysis followed a three step approach beginning with the descriptive analysis followed by the measurement model and the structural model analyses. Section 5.1 presents the descriptive analysis conducted using SPSS version 23. Structural equation modelling approach using AMOS version 23 together with the SPSS was employed for the measurement model and structural model analyses. The choice of AMOS for this part of the analysis was informed by its veracity for the technique (Chin, 1998). Sections 5.2 and 5.3 contain the results of the measurement and structural analysis respectively.

5.1 Descriptive Analysis

Five key attributes of the respondents were analyzed to understand their demographic characteristics. These are gender, age distribution, highest educational level, monthly income and experience with FinTech usage. The results indicate that with the gender groupings the sample is dominated by males (56.4%) and females (43.6%). Majority of the respondents in terms of age distribution are between the ages of 31 - 40 (51.1%) followed by 18 - 30 (24.5%), 41 – 50 (21.6%), and 1.4% each for 51 – 60 and above 60 years. The result is a clear indication that the sample has the dominance of young adults. First degree holders dominate respondents' educational characteristics with 47.5%, followed by post-graduate (31.9%), diploma/HND (16.7), Secondary/High School (2.1%) and certificate holders (1.8%). The gross monthly income of respondents is characterized by the dominance of those who earn between GH¢ 2001 – 3000 (31.6%) followed by GH¢ 1000 – 2000 (23.8%), and 3001 – 4000 (14.9%). While 12.1% of respondents earn above GH¢ 4000, 8.5% of them were reported as receivers of no income. In terms of experience with the use of FinTech, majority of respondents have over one year experience (93.6%) in usage. The rest are 6 – 12 months (4.6%), less than 3 months (1.1%) and lastly 3 – 6 months (0.7%).

5.2 Measurement Model

A confirmatory factor analysis was conducted to estimate how fit the model was with the data collected. Fornell & Larcker, (1981) suggest that before testing whether there are significant relationships in the structural model, the measurement model has to be tested for satisfactory levels of reliability and validity. Indicator and construct reliability, convergent validity as well as divergent validity were evaluated. A good fit was demonstrated by the measurement model given that most of the factor loadings exceeded the 0.7

threshold (Hair et al., 2013). Construct reliability was tested by calculating the composite reliability (CR) which according to Hair et al., (2013), a value of at least 0.7 indicates a good scale reliability. The CR for all constructs exceeded 0.7 except Facilitating Conditions, Price Value, Resource and Behavioural Intention which recorded values a little below 0.7. The construct reliability was further tested using Cronbach's alpha and all constructs recorded above 0.7 values indicating acceptable level of reliability (Straub, 1989). The criterion of average variance extracted (AVE) was used to test for convergent validity and all constructs having at least 0.5 AVE indicate a satisfactory level (Hair et al., 2013). To satisfy requirements for divergent validity, a construct's AVE must exceed the square of the corresponding inter-construct correlations or vice versa (Fornell & Larcker, 1981). The square root of the AVE in diagonal exceed values of the correlation between the constructs, which indicate satisfactory divergent validity by the constructs.

5.3 The Structural Model and Hypotheses Testing
Majority of the model-fit indices exceeded the acceptable thresholds: Chi Square/df = 2.823, RMSEA = 0.081, AGFI = 0.671, PCFI = 0.800, and PNFI = 0.750. The overall values provided evidence for the model's goodness-of-fit. From here the analysis proceeded to examine the path coefficients. Results for the causal paths properties namely standardized path coefficients (β), standard error and hypotheses are presented in Tables 1 and 2.

The model explains 63.1% of behavioural intention, 31.5% of use behaviour, and 10.2% of financial inclusion. Performance Expectancy, Facilitating Conditions and Habit, were found to have statistically significant impact on Behavioural Intention, and Facilitating Conditions and Habit also with significant impact on Use Behaviour, all with $p < 0.01$. Therefore hypotheses H1, H4a, H4b, H7a and H7b were supported. Behavioural Intention was found to have significant effect on Use Behaviour with Use Behaviour also impacting significantly on Financial Inclusion in support of hypotheses H8 and H12 respectively. Conversely, Effort Expectancy, Social Infuence, Hedonic Motivation and Price Value did not have significant influence on Behavioural Intention and so hypotheses H2, H3, H5 and H6 were not supported (Table 1). The moderating effects of Access, Resource and Force were all found to have statistical significance with $p < 0.001$, thus hypotheses H9, H10 and H11 were supported (Table 2).

6.0 Discussions
6.1 Main Findings
This study examined financial inclusion antecedents with the use of FinTech amidst moderators of the digital divide. This was motivated by the paucity of empirical studies on FinTech use and its contributions to achieving financial inclusion, and how the use is affected by the digital divide. In consistence with prior research for example Chopdar et al., (2018) and Oliveira et al., (2016), results of the study indicate a significant influence of performance expectancy on behavioural intention to use FinTech. This is a confirmation suggesting that the use behaviour of FinTech is driven by its associated benefits. The results also indicate the significant influence of facilitating conditions on both behavioural intention and use behaviour of FinTech. This is similar to findings of Chopdar et al., (2018) and Macedo, (2017). Ownership of a mobile phone is the main facilitating condition for the use of most FinTech services and a lot of such services for example mobile money, does not require specialized skills. However, the same cannot be said of other FinTech services such as crowdfunding, wealth management, insurance, cryptocurrency, etc. The significant influence of habit on both behavioural intention and use behaviour is consistent with Baudier et al., (2020) and Chopdar et al., (2018). This result underscores the assumption that there is the higher likelihood of repeated use the more people use Fintech services. The influence of the three digital divide moderators on behavioural intention over use behaviour were validated by the model. In line with expectations access, resource and force had strong positive moderating effects on FinTech use (Haan, 2005; Yu et al., 2018).

Table 1: Summary of Hypotheses Testing Results

			Estimate	S.E.	C.R.	P	Label
Behavioural Intention	<---	Performance Exp.	.115	.033	3.479	***	Accepted
Behavioural Intention	<---	Effort Expectancy	-.002	.063	-.033	.973	Rejected
Behavioural Intention	<---	Social Influence	-.113	.064	-1.762	.078	Rejected
Behavioural Intention	<---	Facilitating Condition	.255	.094	2.701	.007	Accepted
Behavioural Intention	<---	Habit	.603	.072	8.387	***	Accepted
Behavioural Intention	<---	Hedonic Motivation.	.043	.065	.663	.507	Rejected
Behavioural Intention	<---	Price Value	.042	.078	.533	.594	Rejected
Use Behaviour	<---	Facilitating Condition	-.415	.089	-4.649	***	Accepted
Use Behaviour	<---	Habit	1.116	.165	6.763	***	Accepted
Use Behaviour	<---	Behavioural Intention	-.461	.195	-2.362	.018	Accepted
Financial Inclusion	<---	Use Behaviour	.145	.038	3.852	***	Accepted

*Note: *** p <= 0.001*

Table 2: Summary of Moderation Effects

Moderator	Relationships	Estimate	S.E.	C.R.	P	Label
Access	UB <--- BI	.771	.160	4.825	***	Accepted
	UB <--- AC	.861	.146	5.884	***	
	UB <--- BI_AC	-.141	.039	-3.668	***	
Resource	UB <--- BI	.660	.141	4.670	***	Accepted
	UB <--- RS	.882	.153	5.762	***	
	UB <--- BI_RS	-.113	.040	-2.797	.005	
Force	UB <--- BI	.716	.140	5.098	***	Accepted
	UB <--- FS	1.238	.146	8.503	***	
	UB <--- BI_FS	-.156	.038	-4.117	***	

*Note: *** p <= 0.001*

6.2 Additional Findings

On the contrary, the study did not confirm the influence of effort expectancy, social influence, hedonic motivation and price value on behavioural intention. Therefore hypotheses H2, H3, H5 and H6 were rejected. While the finding with effort expectancy is in consistence with Faria, (2012) and Zhou et al., (2010) it is not so with Carlsson et al., (2006) and Im et al., (2011). This finding can be as a result of the high level of mobile phone usage in Ghana. Thus users find using FinTech quite easy and get accustomed to it and so do not expect many problems. With the association of social influence and behavioural intention to use FinTech, there is consistence of the finding with studies like Kim et al., (2009) and Wang & Yi, (2012) but inconsistent with Macedo, (2017). It can thus be inferred that the opinions of significant people do not play much a role in decisions to use FinTech. The finding that hedonic motivation does not influence behavioural intention is in tandem with that of Oliveira et al., (2016) but inconsistent with Chopdar et al., (2018). Thus the inference that people see the use of FinTech as a serious endeavor rather than being fun.

6.3 Theoretical Implications

This study presented a theoretical model which is unique given that UTAUT2 of Venkatesh et al., (2012) was combined with digital divide moderators from Yu et al., (2018) in order to explain how FinTech usage impacts on financial inclusion. Addressing the research questions has led the study to also offer a lot of theoretical contributions. First of all our study extends the applicability of UTAUT2 given the paucity of studies that apply the UTAUT2 to study FinTech services. Our research model accounts for 63.1% predictive accuracy. This is an indication that the study makes a useful contribution to knowledge as compared to the widely-used TAM which often account for between 32% and 53% variance explained (Liébana-Cabanillas et al., 2019). Secondly, the integration of the two theories establishes that FinTech use

depends on both behavioural intentions and the effects of the digital divide. The study demonstrates uniquely how access, resource and force influence the use of FinTech.

6.4 Practical Implications for Policies

Some practical implications are also offered by the study. Performance expectancy among the factors is identified by the study as the most significant, an indication that users will continue using FinTech so far as it offers them needed benefits. This suggests that FinTech service providers can drive acceptance and use if they can redesign, refine and implement their services to cater for more financial needs of users. Findings of the study calls for development of policies to deepen financial inclusion. Habit which was found to be among the important factors suggests the need for policies that will seek to reinforce the use of FinTech services to drive financial inclusion.

The study further reveals that access, resource and force as pertain to the digital divide, play a significant role in the use of FinTech. It is indicative from the results that negative effects of the digital divide mitigate the use of FinTech and the opposite is true. To drive financial inclusion, it is paramount for government and public organizations to endeavor bridging the digital divide through the provision of very affordable/low-cost or free or digital services/devices to boost material access among different categories of people.

7.0 Conclusion

The study intended to investigate the use of FinTech services and its impact on financial inclusion albeit effects of the digital divide. Two theories, UAUT2 and the theory of digital inequality were integrated to develop and examine a unique research model. The results confirmed the influence of performance expectancy, facilitating conditions, habit and behavioural intentions on the use of FinTech services. More importantly, a new insight was offered by the results that the digital divide measured with access, resource and force moderated the use of FinTech. More importantly, the results also indicate the positive influence of FinTech use on financial inclusion. Few limitations affecting the study include the use of convenience sampling of FinTech users. Secondly, due to social idiosyncrasies, results of the study may not apply to the contexts of developed countries given that the research context is in an emerging economy which is Ghana. In order to strengthen generalizability of findings therefore, both developing and developed country contexts may be combined in future research.

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The significance of key constructs on consumer purchase intention in online retail in a Covid-19 climate

Eden Pillay[1], Thembekile Mayayise[2]
[1]WBS, faculty of commerce,law and management , Johannesburg,South Africa

[2]IS, faculty of commerce,law and management, Johannesburg,South Africa

Eden.pillay@gmail.com
Thembekile.Mayayise@wits.ac.za

Abstract

The unexpected outbreak of the COVID pandemic has affected many people and businesses in different ways. As consumers no longer felt safe going to shopping centres they considered online shopping. In South Africa, the online retail market is in its infancy and this presents an opportunity for businesses to capitalise on the current climate.This study investigated the significance of constructs associated with online consumer purchase intention (PI) in South Africa (SA) in a Covid-19 environment. A combination of the Technology Acceptance Model(TAM) and Unified Theory of Acceptance and Use of Technlogy-2(UTAUT2) model were used as a basis for the study including COVID-19 as a situational factor. A sample of 368 South African consumers participated in the study through an online survey. The results of this quantitative study revealed that the most significant constructs in determining consumers' online retail PI in the current environment in SA are Covid-19 and Perceived ease of use(PEOU). The moderation impact of Covid-19 was significant on risk, trust, Perceived Usefulness(PU), PEOU, and Price Value(PV). The implications of this study provide many opportunities for businesses to focus on becoming agile and innovative to drive their online sales.

Keywords: Covid-19, E-Commerce, Purchase Intention, TAM, UTAUT2

1 Introduction

The outbreak of Covid-19, , has resulted in 50,266,033 confirmed cases of infection, 1,254,567 confirmed deaths, and 219 affected countries as at November 9, 2020 (WHO, 2020). The global pandemic has led to lockdowns in different countries, where as a precautionary measure, people are expected to wear masks, keep social distancing, and adhere to curfew regulations. The COVID-19 pandemic has been described as the worst humanitarian crisis since World War 2 (Chen, 2020).On the other-hand, Covid-19 provides an opportunity for businesses to drive their online retail, which benefits both consumers and businesses.

There is a significant difference in SA between the percentage of internet users who visit an online store and those who eventually purchase a product (Hootsuite, 2019). The percentage of internet users that use mobile devices to make online purchases is 38% (Hootsuite, 2019).In SA, the online retail market is still immature. In 2018, online retail spending amounted to R14bn, representing a mere 1.4% of the total retail sales (Worx, 2019). This is significantly less than the global share of online retail to total retail sales of about 15%(Steyn and Mawela 2016), which reinforced the considerable underperformance of online retail in SA. However, the Covid-19 environment allows businesses to increase activity and transactions in the online retail market. From a retail perspective, Business to consumer (B2C), Business to Business (B2B), and Consumer to Consumer (C2C) are the primary models in e-commerce (C. S. Lee, 2001). In South Africa, Takealot which is an example of a B2C e-commerce market type and Gumtree, which is an example

of a C2C e-commerce market type rank among the top 10 list of South African leading websites visited, with approximately 7-9 million views a month (Hootsuite, 2019).

According to Clement (2020), online retail is expected to grow at 56% globally. Importantly, in terms of percentage of total retail sales, online retail in SA needs to scale up to be on par with other countries. This study aims to investigate the significance of constructs that influence consumer perceptions in online retail in South Africa.

1.1 Purpose of the Study

To succeed in online retail, businesses need to understand consumer perceptions of online retail. A negative experience on a retail website can have lasting adverse consequences for the business. Therefore, businesses must understand the key constructs that affect consumers' perceptions of online retail, especially under the current COVID climate.

Therefore, the aim of this study is to determine the significance of constructs on consumer perceptions in online retail in the current Covid-19 environment. A combination of TAM model constructs i.e. risk, trust, Perceived Usefulness(PU) , Perceived Ease Of Use(PEOU) will be used by Pavlou (2003). In addition, Price Value, Facilitating Conditions from the Unified Theory of acceptance and use of technology model (Venkatesh et al. (2012) are included in the adapted model as depicted in Figure 1 as key constructs. These constructs are regarded as key because of the potential effect they are likely to have on the purchase intention. The inclusion of Covid-19 as a situational factor in the adapted model will help determine its significance and how it is shaping consumer perceptions in online retail. The moderation impact of Covid-19 on the other constructs will also be analysed. Various e-commerce studies have analysed purchase intention in a multi-faceted manner. Adoption studies continue to focus on consumer purchase intention because of the view that intention can be used to anticipate actual behavior.Covid-19 has not been used to test its effect on consumer purchased intention in the South African context; hence this study was initiated.

This study will provide businesses with insights into the significance of the constructs in consumer perception. It will allow businesses to focus both on positive and negative significant constructs, which will help design methodologies to adapt their online retail channels. Furthermore, it will shed light on the reality of the impact of Covid-19 on consumer perceptions of online retail in SA.

 The proposed theoretical model for this study is in section in Figure 1.

The main research questions are:

1a. What is the significance of risk, trust, PU, PEOU, PV, FC, and Covid-19 on consumer Purchase intention(PI) in online retail in SA?

1b. What is the moderation impact of Covid-19 on risk, trust, PU, PEOU, PV, and FC on consumer online PI in SA?

2. Literature review

2.1 Theoretical Background and Research Model

Numerous models have been developed to understand the adoption behavior and intention of individuals (Nedra, Hadhri, & Mezrani, 2019). Table 1 details a few of these models, their development over time, and the authors who developed them. Importantly, this is not an exhaustive list as listing all existing models is beyond the scope of this paper.

Table 1: Adoption frameworks

Model	Date Developed	Main Constructs	Source
Theory of Reasoned Action (TRA)	1980	Attitude Toward Behavior; Subjective Norm	(Fishbein & Ajzen, 1980)
Technology Acceptance Model (TAM)	1989	Perceived Usefulness; Perceived Ease of Use; Subjective Norm	(Davis, 1989)
Theory of Planned Behavior (TPB)	1991	Attitude Toward Behavior; Subjective Norm; Perceived Behavioral Control	(Ajzen, 1991)
TAM 2	2000	Subjective Norm; Image; Job Relevance; Output Quality; Results Demonstrability; Experience; Voluntariness	(Venkatesh & Davis, 2000)
Extended TAM	2003	Perceived Usefulness; Perceived Ease of Use; Trust; Risk	(Pavlou, 2003)
Unified Theory of Acceptance and Use of Technology (UTAUT)	2003	Performance Expectancy; Effort Expectancy; Social Influence; Facilitating; Conditions; Gender; Age; Experience, Voluntariness of Use	(Venkatesh et al., 2003)
UTAUT 2	2012	Performance Expectancy; Effort Expectancy; Social Influence; Facilitating; Conditions; Hedonic Motivation; Price Value; Habit; Gender; Age; Experience	(Venkatesh et al., 2012)

As can be seen in Table 1, several models aim at predicting an individual's adoptive behaviour. TAM, derived from the Theory of Reasoned Action model, is based on the notion that the adoption of technology is not based solely on intrinsic motivations measured by TRA, such as attitude and subjective norm. Davis (1989) added two external factors, PU and PEOU, into the model. Pavlou (2003) extended the TAM model to include the elements of trust and risk. This extended TAM model by Pavlou (2003) is the most relevant model for understanding the impact of Covid-19 on consumer PI in the current environment. It includes extrinsic factors and intrinsic factors that contribute to a consumer's intention to purchase. The UTAUT model, developed by Venkatesh et al. (2003), combines key constructs from eight other models to understand user acceptance. Venkatesh et al. (2012) developed the UTAUT2 model, which is an extension of the UTAUT model, to analyse intention in a consumer context. The model has been successful and efficient in predicting the behavior and intention of consumers. Many studies have used the model to predict consumer behavior and intention in different contexts. Therefore, two constructs, PV and FC from the UTAUT2 model, are also included in the model used in this study.

Covid-19 is a situational factor affecting the ability of consumers to perform certain activities. Therefore, it is also included in the adapted TAM model. Monsuwé, Dellaert, and De Ruyter (2004) describe situational

factors as exogenous determinants and introduce them into the TAM model, which has a significant impact on consumer online shopping experience.

However, after evaluating these models and applying them to the current context of the pandemic, the extended TAM model by Pavlou (2003), as well as PV and FC from the UTAUT2 model, were more appropriate and relevant as the basis of this study as depicted in Figure 1.
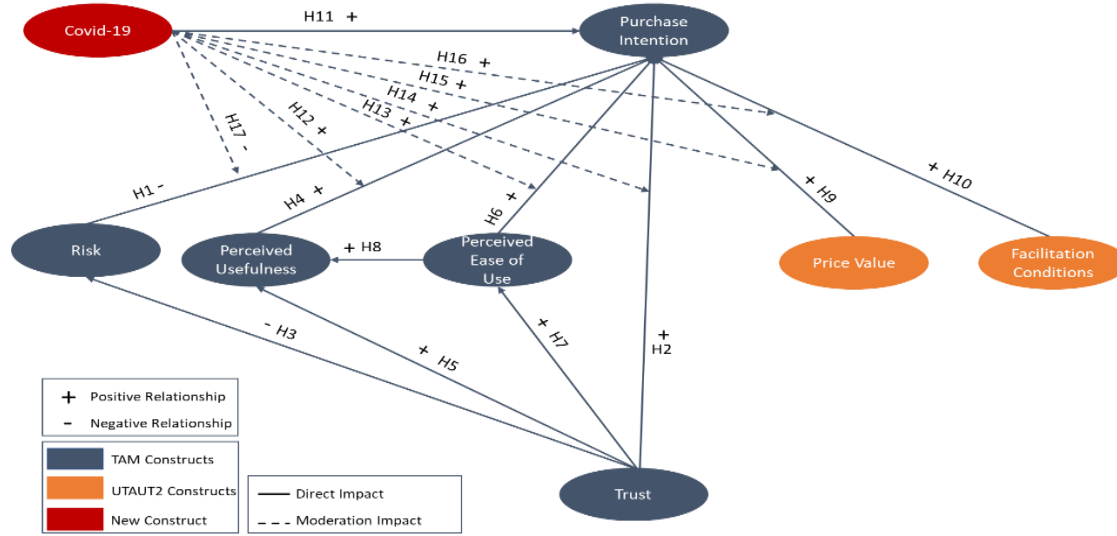
Figure 1: Proposed research model: Adapted from (Pavlou, 2003; Venkatesh et al., 2012)

Based on the research model in Figure 1 and the findings from the literature review from section 2, seventeen hypotheses were proposed based on all the constructs in Figure 1.

2.2 Factors affecting consumer purchase intention

2.2.1 Risk

Certain risks are inherent in online retail businesses (Featherman & Pavlou, 2003; Spiekermann & Paraschiv, 2002). The perceived risk factors affecting online purchases are performance, financial, time, self-esteem, social status, and privacy (Featherman & Pavlou, 2003). Consumer trust in e-commerce can help overcome the risks mentioned above and enhance e-commerce activity. According to Mou, Shin, and Cohen (2017), trust and risk are critical factors in understanding consumer PI in online retailing. The importance of both trust and risk as significant factors in consumer perceptions of e-commerce have been confirmed by Mou et al.(2017).In this study, risk has been Hypothesised as follows:

 H1: Risk is negatively associated with consumer PI.

2.2.2 Trust

Trust comprises three primary characteristics: ability, benevolence, and integrity (Mayer et al., 1995). Online trust comprises two constructs, general and specific trust, each having two dimensions (Thatcher, Carter, Li, & Rong, 2013). Technology infrastructure and institutional mechanisms are the two dimensions

of general trust, whereas the merchant and website are the dimensions of specific trust (Thatcher et al., 2013). In SA, the government, industry, and regulatory institutions must focus on general trust constructs to create an environment for e-commerce and m-commerce activity to flourish. In this study, specific trust has been considered. Many studies have highlighted that perceived risk negatively affects a consumer's PI, whereas trust, both directly and indirectly, positively affects buying intent. In addition, trust has a negative effect on risk (Dinev et al., 2006; Featherman & Pavlou, 2003; Garbarino & Strahilevitz, 2004). In SA, a study on consumer online retail PI conducted by Steyn and Mawela (2016) found trust to be a significant factor for consumers to complete transactions online. In this study the following hypothesis statements have been formulated regarding Trust:

H2: Trust is positively associated with consumer PI

H3: Trust is negatively associated with consumer perceived risk

H5: Trust is positively associated with consumer PU

H7: Trust is positively associated with consumer PEOU.

2.2.3 Perceived Usefulness

PU refers to consumer perception of the value of utility derived from using technology. Davis (1989) defines PU as "PU is the extent to which a person believes that using a particular technology will enhance his or her job performance"(p.320). In this context, PU is the utility value, such as convenience, product availability, low cost, and bypassing of physical interaction, that consumers benefit from when shopping online. In a South African context, PU is critical because convenience is an important predictor of PI (Steyn & Mawela, 2016). Perceived usefulness has been hypothesised as follows:

H4: PU is positively associated with consumer PI

2.2.4 Perceived Ease of Use

PEOU refers to consumers' perception of how easy it is to use a particular technology. In online retail, it is the process of learning how to shop online, from visiting relevant websites to completing the transactions and receiving goods and services. The level of difficulty, as perceived by consumers, of completing all of these steps in online retail will influence their PEOU, an essential factor in predicting PI. Taufik and Hanafiah (2019) concluded that PEOU significantly affects consumer intention to adopt self-service technology.

In a Covid-19 environment, the role of PEOU in online retail must be understood for businesses to react appropriately to consumer perceptions. Perceived Ease of Use has been hypothesised as follows

H8: PEOU is positively associated with consumer PU

H6: PEOU is positively associated with consumer PI

2.2.5 Price Value

There are costs associated when a consumer shops online, such as data, convenience, delivery, and transaction expenses. Dodds et al. (1991) describe PV as the "amount of sacrifice needed to purchase a product" (p.308). In this context, PV refers to the trade-off between the perceived benefit of shopping online

and the cost of online shopping. Therefore, the PV is positive when the perceived benefits of shopping online are higher than the cost (Venkatesh et al., 2012). Venkatesh et al. (2012) included PV as a significant construct in the UTAUT2 model to predict consumer adoption of technology. Price value has been hypothesised as follows:

H9: PV is positively associated with consumer PI.

2.2.6 Facilitating Conditions

FC refers to consumers having the necessary access and devices to shop online (Venkatesh et al., 2003; Venkatesh et al., 2012). In a South African context, the digital and economic divide prejudices a large portion of the population from shopping online (Armstrong, 2020a).

Venkatesh et al. (2003) developed the UTAUT model to predict technology acceptance in an organisational context. They discovered that FC was a significant predictor of individuals' adoption of technology. Facilitating Conditions have been hypothesised as follows

H10: FC is positively associated with consumer PI

2.2.7 Situational Factors – Covid-19

The impact of Covid-19 on businesses is still unclear, posing a challenge to predict the future of businesses. The Board of Innovation has compiled a report attempting to provide businesses with a view of what the potential of the low touch economy may look like (Mey & Ridder, 2020). The report states that people and organisations will adapt to new ways of living, challenging traditional behavioral norms (Mey & Ridder, 2020). Bhargava et al. (2020) indicate a considerable increase in digital activities during the period. They also expect a decrease in physical shopping at stores and malls (Bhargava et al., 2020). Covid-19 has also affected consumers' disposable income due to job losses, salary cuts, and increases below inflation (Bhargava et al., 2020).

The environment that consumers are in, referred to as situational factors, plays a significant role in their purchase behaviours (Hand, Riley, Harris, Singh, & Rettie, 2009). The situational factors, which influence and shape consumer behaviours, cannot be controlled or influenced in any way by consumers themselves (Engel & Blackwell, 1982; Haugtvedt, Petty, & Cacioppo, 1992; Monsuwé et al., 2004). Therefore, Covid-19 can be classified as a situational factor as it is shaping businesses, societies, and the lives and behaviour of individuals. The Covid-19 environment has forced customers to find alternative channels to purchase goods and services.COVID-19 has been hypothesised as follows:

H11: Covid-19 is positively associated with consumer PI H12: Perceptions of the Covid-19 impact act as a moderator such that the relationship between trust and PI is stronger when the effect of the situational factor is higher

H12: Perceptions of the Covid-19 impact act as a moderator such that the relationship between trust and PI is stronger when the effect of the situational factor is higher

H13: Perceptions of the Covid-19 impact act as a moderator such that the relationship between PU and PI is stronger when the effect of the situational factor is higher

H14: Perceptions of the Covid-19 impact act as a moderator such that the relationship between PEOU and PI is stronger when the effect of the situational factor is higher

H15: Perceptions of the Covid-19 impact act as a moderator such that the relationship between price value and PI is stronger when the effect of the situational factor is higher

H16: Perceptions of the Covid-19 impact act as a moderator such that the relationship between facilitating conditions and PI is stronger when the effect of the situational factor is higher

H17: Perceptions of the COVID-19 impact act as a moderator such that the relationship between risk and PI is weaker when the effect of the situational factor is higher

2.2.8 Purchase Intention

For online retailing to accelerate, factors driving consumer PI must be determined. PI is considered a strong indicator of actual behaviour. Pavlou and Fygenson (2006) found that PI was significant in predicting purchase behaviour in a B2C online environment.The findings were in line with Ajzen (1991) that behaviour intention is a strong predictor of actual behavior. The factor of PI has been applied widely to study user adoption and predict actual behavior.

3. Research methodology

3.1 Research paradigm and approach

A positivist research paradigm was followed for this study which is a quantitative study conducted in South Africa on online retail. Similar studies have been conducted within a positivist paradigm (Awa et. Al., 2016). Qualtrics software was used to design an online questionnaire used for data collection. It was distributed to a total of 368 South African consumers capable of performing online shopping. A snowball and convenience sampling techniques were used to reach the appropriate number of responses required.

3.2 Data analysis

Structural equation modelling formed part of the major analysis methodology to test the main model (Hair, Hult, Ringle, Sarstedt, & Thiele, 2017). The results begin with bivariate Pearson correlations to test for simple linear associations between the constructs, including demographics.

3.3 Validity and reliability

The following reliability and validity issues are relevant to the study.

3.3.1 Reliability

The internal reliability of the constructs is directly assessed through Cronbach alpha and factor analyses. An alpha value of 0.7 is the acceptable threshold for reliability (Lee, 2015). Generalisability is limited due to the focus on South African consumers. However, the results can be extrapolated to other contexts worldwide because digitally connected consumers often share similar preferences.

3.3.2 Internal validity

The closed-form questions were selected for their content validity and prior use in similar studies. Construct validity is tested directly in this study using CFA. The structural equation model can test predictive validity against a known model and theory set, therefore testing directly for model validity.

4. RESULTS

4.1 Sample Demographics

Table 2 details the demographic distribution of the surveyed sample.

Table 2: Demographic and Other Variables of the Sample Population.

Demographics & Other Variables	Category	N(n=376)	% Contribution
Gender	Male	139	37%
	Female	237	63%
Age	20 to 24	97	26%
	25 to 29	85	23%
	30 to 34	70	19%
	35 to 39	54	14%
	36 to 39	57	15%
	50 to 64	12	3%
	>65	1	0%
Education	Completed high school	36	10%
	Diploma	6	2%
	Bachelors degree	93	25%
	Honours/Post Graduate	132	35%
	Masters	97	26%
	PHD	12	3%
Household Income	0 to R4,999	24	6%
	R5,000 to R9,999	23	6%
	R10,000 to R19,999	31	8%
	R20,000 to R39,999	74	20%
	R40,000 to R69,999	84	22%
	R70,000 to R99,999	32	8%
	>R99,999	59	16%
	Prefer not to say	48	13%
Online Shopping Experience	No experience	21	5%
	Limited experience	47	13%
	Moderate experience	126	33%
	Above average experience	82	22%
	Extensive experience	101	27%

4.2 Correlational Analysis

The first analyses presented utilise Pearson correlations to investigate bivariate correlations between construct pairs. Table 3 shows the correlation coefficients as well as basic descriptive statistics, noting that these analyses are based on construct factor scores from the CFA. In addition, the control variables were also included in the correlation matrix to identify any significant impacts that they may have on PI or any of the other constructs Online PI is highly correlated with PU (r = .73, p < .01), PEOU (r = .73, p < .01), COVID-19 (r = .63, p < .01), trust (r = .61, p < .01), and PV (r = .57, p < .01), and moderately correlated with FC (r = .49, p < .01) and prior experience (r = .52, p < .01). As also expected by the model, trust is positively correlated with PU (r = .70, p < .01) and PEOU (r = .72, p < .01), although surprisingly trust and risk are also positively correlated (r = .38, p < .01) which is contrary to H3. A final path in the model involves an expected association between PU and PEOU, which is strongly supported with r = .83, p < .01.

Table 3: Correlation analysis

	M	SD	1.	2.	3.	4.	5.	6.	7.	8.	9.	10	11	12
1. PI	.00	.95	1.00											
2. PU	.00	.92	.73***	1.00										
3. Risk	.40	1.54	.35***	.30***	1.00									
4. PEOU	.00	.93	.73***	.83***	.35***	1.00								
5. PV	.00	.90	.57***	.82***	.31***	.69***	1.00							
6. FC	4.21	2.78	.49***	.57***	.27***	.63***	.47***	1.00						
7. Trust	.00	.91	.61***	.70***	.38***	.72***	.64***	.50***	1.00					
8. COVID-19	.00	.89	.63***	.54***	.20***	.42***	.38***	.29***	.37***	1.00				
9. Female	.37	.48	.06	.07	.07	.08	.07	.04	.07	-.05	1.00			
10. Age	3.98	1.06	.05	.05	.04	.02	.08	.02	.10*	.02	.13**	1.00		
11. Education	5.77	1.23	.03	.00	.00	.01	.08	-.01	.03	-.05	.07	.45***	1.00	
12. Income	5.51	1.74	.27***	.27***	.08	.25***	.29***	.30***	.26***	.23***	-.03	.35***	.15***	1.00
13. Experience	3.56	1.14	.52***	.49***	.31***	.53***	.38***	.42***	.41***	.23***	.05	.11*	.12*	.34***

Notes: M = Variable mean, SD = standard deviation, *** = p < .01, ** = p < .05, * = p < .10

5. DISCUSSION

5.1 Summary of Results

Table 4 gives a high-level view of each hypothesis and the outcome of the research. Each hypothesis will be discussed in detail:

Table 4: Summary of results

Hypothesis	Measure	Result	Outcome
H1	Risk is negatively associated with consumer PI	$\beta = -0.03$; p-value >0.10	Not Supported
H2	Trust is positively associated with consumer PI	$\beta = 0.11$; p-value > 0.10	Not Supported
H3	Trust is negatively associated with consumer perceived risk	$\beta = 0.02$; p-value > 0.10	Not Supported
H4	PU is positively associated with consumer PI	$\beta = 0.17$; p-value < 0.10	Not Supported
H5	Trust is positively associated with consumer PU	$\beta = 0.02$; p-value > 0.10	Not Supported
H6	PEOU is positively associated with PI	$\beta = 0.26$; $p < 0.01$	Supported
H7	Trust is positively associated with consumer PEOU	$\beta = 0.46$; $p < 0.01$	Supported
H8	PEOU is positively associated with consumer PU	$\beta = 0.49$; $p < 0.01$	Supported
H9	PV is positively associated with PI	$\beta = 0.00$; p-value > 0.10	Not Supported
H10	FC is positively associated with consumer PI	$\beta = -0.02$; p-value > 0.10	Not Supported
H11	Covid-19 is positively associated with consumer PI	$\beta = 0.32$; $p < 0.01$	Supported
H12	Perceptions of the Covid-19 impact act as a moderator such that the relationship between trust and PI is stronger when Covid-19 impact is higher	$\beta = -0.08$; $p < 0.01$	Moderation Impact Supported;
H13	Perceptions of the Covid-19 impact act as a moderator such that the relationship between PU and PI is stronger when Covid-19 impact is higher	$\beta = -0.11$; $p < 0.01$	Moderation Impact Supported;
H14	Perceptions of the Covid-19 impact act as a moderator such that the relationship between PEOU and PI is stronger when Covid-19 impact is higher	$\beta = -0.07$; $p < 0.01$	Moderation Impact Supported;
H15	Perceptions of the Covid-19 impact act as a moderator such that the relationship between PV and PI is stronger when Covid-19 impact is higher	$\beta = -0.09$; $p < 0.01$	Moderation Impact Supported;
H16	Perceptions of the Covid-19 impact act as a moderator such that the relationship between FC and PI is stronger when Covid-19 impact is higher	$\beta = -0.01$; p-value >0.10	Not Supported
H17	Perceptions of the COVID-19 impact act as a moderator such that the relationship between risk and PI is weaker when COVID-19 impact is higher	$\beta = -0.09$; p-value <0.01	Moderation Impact Supported;

5.2 Findings discussions

H_1: Risk is negatively associated with consumer purchase intention

The results of the research do not support H1. Under the COVID climate, even though consumers may perceive online shopping as risky, they do not have much choice but to buy online. This finding is similar to Suh, Ahn, Lee, and Pedersen (2015) and Ventre and Kolbe (2020).

H_2: Trust is positively associated with consumer PI

The results of the research do not support H2. This can be attributed to the circumstances of the COVID climate trust in online retail seems to have little influence on whether customers intend to purchase online or not. This is contrary to many studies over the years that have shown that trust is a critical construct in positively influencing consumers PI (Dinev et al., 2006; Glover & Benbasat, 2010; Hong, 2015).

H_3: Trust is negatively associated with consumer perceived risk

The results of the research do not support H3.Again, this is in line with the findings from H1 and H2 because both risk and trust do not impact consumers PI in online retail.

H_4: PU is positively associated with consumer PI

There is limited support for H4 in this research, albeit it is insignificant at a p-value of <0.05 and <0.01. Therefore, for the purposes of this research, H4 is rejected. Other studies also found similar results in their study on online shopping, found that PU was also not a significant factor in consumer PI(Dachyar & Banjarnahor, 2017).

H_5: Trust is positively associated with consumer PU

The research does not support H5. This is in line with the findings of H3 in which trust does not impact risk. The overriding environment in which the Covid-19 pandemic is dictating consumer behaviour is what driving consumers' intention to purchase online is.

H_6: PEOU is positively associated with PI

The research supports H6.This finding validates previous research that shows PEOU impacts consumers online PI positively (Cho & Sagynov, 2015; Guritno & Siringoringo, 2013; Hansen et al., 2018)

H_7: Trust is positively associated with consumer PEOU

There is support for H7 in this research. Although trust does not impact PI, risk and PU in this study, it does significantly impact PEOU positively and this agrees with the outcome of the research by Pavlou (2003).

H_8: PEOU is positively associated with consumer PU

The research supports H8 significantly. PEOU does impact consumers PI not only directly but also indirectly through its impact on PU. The positive impact of PEOU on PU is in line with previous studies (Cho & Sagynov, 2015; Pavlou, 2003).

H_9: Price Value is positively associated with PI

There was no support for H8 in this research. PV does not impact consumers online PI because consumers may be forced to shop online, whether their PV from shopping online is positive or negative. This is contrary

to previous studies outcomes (Kim et al., 2007; Venkatesh et al., 2012). Additional Relationship 1: Price Value is positively associated with perceived usefulness. However, during the analyses of the data using the Structural Equation Modelling, a relationship between PV and PU was identified. The relationship is significant and directionally is expected. If consumers perceive high PV, then their PU will also be high. This is because both constructs encapsulate the positive utility of shopping online versus the negative utility. It follows the valence framework theory, which states that consumers perceive positive and negative utility value from completing a transaction (Mou et al., 2019). Therefore, the findings in this study support the relationship of PV positively impacting PU.

H10: Facilitating conditions is positively associated with consumer PI. The research does not support H10. Additional Relationship 2 has been identified of facilitating Conditions which is positively associated with perceived ease of use, and it is supported by findings in previous research (Venkatesh, 2000).

H11: Covid-19 is positively associated with consumer PI

There is support in this research for H11. Covid-19 has the most significant direct impact on consumers online PI. Situational factors act as a motivator that influences consumers to take a specific action (Haugtvedt et al., 1992). The situational factor Covid-19 is the motivational factor in the current climate that is driving consumers PI. This is a critical finding because Covid-19 will still have a major impact in SA and around the world in the short- to medium-term. Therefore, retailers need to ensure that they can capitalise on the opportunity to grow their sales through online retail.

Additional Relationship 3: Consumer online shopping experience is positively associated with PI

During the analyses of the data, a significant relationship between consumer online shopping experience and PI was discovered. Venkatesh (2000) and Venkatesh et al. (2012) found in their study that experience plays a significant role in determining consumers behavior intention. Consumer online shopping experience is an important factor that is significant in determining PI.

Moderation Impacts

H12: Perceptions of the Covid-19 impact act as a moderator such that the relationship between trust and PI is stronger when Covid-19 impact is higher

There is support for the moderation impact of Covid-19 on trust in this research; however, contrary to H12 Covid-19 moderates the relationship between trust and PI such that it is weaker when the Covid-19 impact is higher. Therefore, a critical insight is that trust is a more important construct the less consumers perceive Covid-19 as a threat. The research shows that under a high consumer perception of Covid-19 as a threat that trust plays a minimal role in consumer's intention to purchase online. This research confirms other research on situational factors, and it's importance in predicting consumer behavior (Ajzen et al., 1982; Baron & Kenny, 1986)

H13: Perceptions of the Covid-19 impact act as a moderator such that the relationship between PU and PI is stronger when Covid-19 impact is higher

There is support for the moderation impact of Covid-19 on PU in this research; however, contrary to H13 Covid-19 moderates the relationship between PU and PI such that it is weaker when the Covid-19 impact is higher. The findings support other research on the impact of situational factors on moderating the impact of other constructs on consumer behaviour (Ajzen et al., 1982; Monsuwé et al., 2004)

H14: Perceptions of the Covid-19 impact act as a moderator such that the relationship between PEOU and PI is stronger when Covid-19 impact is higher

There is support for the moderation impact of Covid-19 on PEOU in this research; however, contrary to H14, Covid-19 moderates the relationship between PEOU and PI such that it is weaker when the Covid-19 impact is higher. The research shows that Covid-19 is the main driver of online consumer PI in a high threat of Covid-19 environment. The findings support other research on the impact of situational factors on moderating the impact of other constructs on consumer behavior (Monsuwé et al., 2004). This reiterates the findings discussed in this study which substantiate that Covid-19 is a stronger predictor of PI overall when consumers perceive a high threat of Covid-19.

H_{15}: *Perceptions of the Covid-19 impact act as a moderator such that the relationship between PV and PI is stronger when Covid-19 impact is higher*

There is support for the moderation impact of Covid-19 on PV in this research; however, contrary to H15 Covid-19 moderates the relationship between PV and PI such that it weakens the relationship when the Covid-19 impact is higher. Therefore, under a high threat of Covid-19 environment, a higher perception of PV results in lower PI.

H_{16}: *Perceptions of the Covid-19 impact act as a moderator such that the relationship between FC and PI is stronger when Covid-19 impact is higher*

There was no support for H16 in this research. This is due to the fact that FC involves the external environment that consumers find themselves in. Covid-19 is a situational factor that has no bearing on consumers FC to conduct online retail.

H_{17}: *Perceptions of the COVID-19 impact act as a moderator such that the relationship between risk and PI is weaker when COVID-19 impact is higher.*

There is support for the moderation impact of risk in this research; however, contrary to H17 Covid-19 moderates the relationship between risk and PI such that it is stronger when the Covid-19 impact is higher. When consumers perceive Covid-19 as a threat, then under a high-risk perception, their intention to purchase is lower than when their risk perception is low. The results from this study support the findings of other researchers on the moderating impact of situational factors impacting consumer behavior (Ajzen et al., 1982).This finding substantiates that Covid-19 has the largest impact on consumers PI in the current environment that consumers find themselves in.

5.2 Limitations of the study

The study followed a quantitative approach and there are several subtle and even unknown factors in the unfolding impact of Covid-19 on businesses and consumers, all of which cannot be analysed in this study .As such, supplementary qualitative research may be used to examine these broader issues.

6. Conclusion

The findings of this study, as depicted in tables 3 and 4 show that Covid-19 and PEOU are the most significant constructs for determining consumer online retail PI under the current pandemic setting in SA. In addition, online shopping experience was found to affect PI significantly. The situational construct Covid-19 had the most significant direct effect on consumer PI in this study. PEOU had the most significant impact when assessing both its direct and indirect influence on consumer online PI. Although Covid-19 was an overriding factor for consumers to shop online, the PEOU of online retailers seemed to be a critical construct for encouraging online purchases. Online shopping experience was also a significant construct impacting the PI of consumers. The moderation impact of Covid-19 was significant on risk, trust, PU, PEOU, and PV. Covid-19 moderated the effect of trust, PEOU, and PU such that the relationship between

these constructs and PI overall are weak under a high-threat environment compared to a low-threat Covid-19 scenario. The findings in this study confirm the significant direct impact of Covid-19 on consumer PI. The situational factor moderates the relationships of consumer PI and validates previous research on situational factors acting as a moderator (Monsuwé et al., 2004).This study is relevant for business in the pandemic environment and into the future to continuously test consumer perceptions that impact their PI.

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Assessing Excel Skills towards Implementation of BI Solutions in Corporate Institutions: The Case of Accountants in Malawi

Umali Leonard, Mtisunge Tupochere Malemia and Patrick Chikumba
Computing and Information Technology, Faculty of Applied Sciences, Malawi University of Business and Applied Sciences, Blantyre, MALAWI
uleonard@mubas.ac.mw
mmalemia@mubas.ac.mw
pchikumba@mubas.ac.mw

Abstract

Effective use of Excel as a BI technology requires advanced skills. The observation is that accountants use Excel is the most common analytical tool. However, they lack advanced skills to utilise Excel for Business Intelligence. Hence, the question is: What are the specific skills for accountants to use Excel as BI tool? The study adopted the qualitative case study approach using two companies (private company and statutory corporation) in which data was collected through participant observations, artefact examination and semi-structured interviews. Findings in this study indicate that accountants in corporate institutions in Malawi perform business intelligence using Vanilla Excel. However, they lack skills particularly in integration of Excel files, advanced formulas and functions, and power tools. To address these Excel skill gaps, corporate institutions need to provide adequate and relevant user-oriented trainings.

Keywords: Business Intelligence, Excel skills, ETL, Power tools, Vanilla Excel

1   Introduction

Business Intelligence (BI) is a concept which is becoming popular in different disciplines such as Information Systems and strategic management. According to Shollo and Kautz (2010), BI involves both a process (methods of developing useful information) and product (information to be used to predict business environment). Cristescu (2017) takes BI as "the process of collecting operational data and use these data to take the best decisions regarding the company" (p. 1). Main components of BI include data warehouse, data analytics, and performance analysis (Wixom and Watson, 2007; Chahal and Gulia, 2016).

BI is taken as a two-part process: getting data in and getting data out which involve gathering data from multiple sources into data warehouse and transforming data for reporting respectively. Data analytics, and performance analysis are part of getting data out. In this paper, the focus is on data analytics which is the method of analysing volumes of data using a set of technologies and techniques (Riahi, 2018) including Excel. In the recent Excel versions (Excel 2016 and 2019, for example), advanced BI features have been added such as Power Pivot and Power Query. Other Excel features such as slicers, timelines, Pivot charts, Pivot table, calculated members and measures can also be used for business intelligence.

To effectively use Excel as a BI technology, advanced Excel skills are required. Excel is commonly used in the business world for analysis and business modeling. With Excel, reports and dashboards can be created for tactical and strategic managers. Geiger (2015) states that 78% of middle-skilled jobs require digital skills like Excel. Excel is one of technologies mainly used in accounting-related processes. Ragland and Ramachandran (2014) point out that Excel is the most common analytical

tool used by accountants. Akroyd et al. (2013) argue proficiency in Excel is especially important given the volume of data that accountants have to analyze.

Jelen and Alexander (2007) state that close to 50% of Excel users leave 80% of Excel untouched, that is, most users do not tap into the full potential of Excel's built-in utilities. Even in Malawi, most accountants do not have adequate Excel skills when graduating from colleges and universities because their accounting curriculums do not emphasise on Excel skills. There is a need to incorporate more accounting-related technical skills like Excel in accounting education (Ragland and Ramachandran, 2014). Rotondo (2020) affirms that Excel skills are the top technology competency required of entry-level accountants. Hence, the lack of Excel skills contributes to the failure to maximally use Excel as BI tool.

However, in literature, it is not explicitly explained what specific skills may be needed by accountants to utilise Excel for BI. In this paper the authors present Excel as a common technology for BI and analysis for businesses in Malawi and explore the Excel skill gaps for both new and existing accountants for using Excel as a BI tool. The paper answers the following question: What are the specific skills for accountants to use Excel as BI tool? The rest of the paper contains related literature on Excel as BI tool, methodology, findings, discussions, and conclusion and recommendations.

2   Business Intelligence and Excel

2.1   BI and its components

Business Intelligence (BI) involves applying tools and techniques to gather and analyze data collected from one or multiple data sources, to create knowledge that helps in decision making (Shollo, 2011). The success of a BI tool largely depends on how much it helps achieve organizational goals, reduce costs throughout the organization, and maximize profitability by identifying the most profitable customers, products, services or programs (Cristescu, 2017). To create the business knowledge, there are three components of BI that must work together namely data warehouse, data analytics and corporate performance analysis as summarised below.

- *Data warehouse*: The data warehouse is the central source of information for the whole enterprise and contains data that is permanent, thematically organized, properly aggregated and time variant (Nowicki et al., 2007). The data warehouse defines the data gathering part of the BI process.
- *Data analytics*: Data analytics allows for continuous iterative exploration and investigation of past business performance to provide actionable insights (Xin, 2014). The analytics done in BI informs the decisions made by management and involves the use of different BI tools like Qlik, PowerBI, Tableau and Excel. With Excel, BI is easier to collate and view (Kaur, 2021).
- *Corporate performance analysis*: Corporate performance analysis is a process used to monitor and manage performance of an organization (Hartl et al., 2016). BI tools and processes allow for the collection and reconciliation of operational data that relates to business processes making it possible to measure the business process performance (Melchert et al., 2004) which then reflects the performance of the organization.

2.2   BI as a two-part process

As illustrated in Figure 1, Watson and Wixom (2007) conceptualized a framework for BI as a two-part process: getting data in and getting data out.
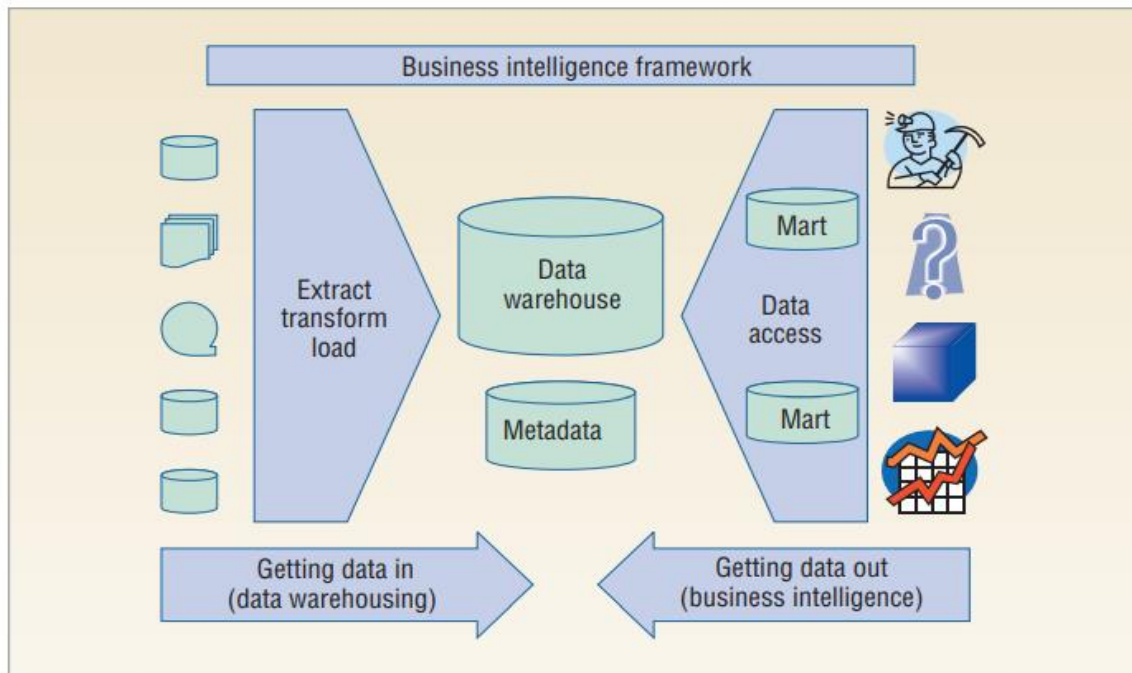
Figure 1: Business Intelligence Framework (Watson and Wixom, 2007, pp. 97)

2.2.1   Getting Data In

Getting data in includes extraction, transformation and loading of data (ETL) (Watson and Wixom, 2007). Watson (2009) argues that ETL may be misleading as in some cases data may be loaded before transformation, hence ELT. However, the paper has adopted the original framework of ETL (Watson and Wixom, 2007). Getting data in is the most challenging and expensive aspect of BI, requiring about 80 percent of the time and effort and generating more than 50 percent of the unexpected project costs (Watson and Wixom, 2007).

Getting data in is all about data warehousing, in which, data from multiple sources are extracted, then transformed to a new format and finally loaded into a data warehouse. Data sources include operational databases and Enterprise Resource Planning (as examples of enterprise databases), Web and other external sources. Data transformation involves consolidation of data from different sources using common keys, removal and addition of columns, calculations of aggregate values, changing of column data formats, and replacing the missing data. During the transformation, metadata is created and stored. According to Watson and Wixom (2007), metadata is technical and business in nature; it describes field values, sizes, ranges, field definitions, data owners, latency, and transformation processes. Metadata provides transparency as data moves from sources to the warehouse to end users (Watson and Wixom, 2007). Once the data has been transformed, it is either loaded into a warehouse or data mart. At this stage, the data is now in a usable form for generation of insights for decision making.

2.2.2   Getting Data Out

Getting data out is the pertinent activity in the BI process because it adds value to the business enterprise. As illustrated in Figure 1, getting data out is commonly referred to as BI which consists of business users and applications accessing data from the data warehouse for data analytics such as

OLAP (Watson & Wixom, 2007). Online Analytical Processing (OLAP) is a general term that refers to analysis techniques with functionalities such as summarization, consolidation and aggregation, as well as the ability to view information from different perspectives (Reddy et al., 2010). OLAP as a database technology allows for data that is highly organized and uses multidimensional structures to provide rapid access to data for analysis.

2.3   Excel as BI Tool

Excel is one of the most used BI tools. For years, BI vendors fought against the use of Excel, but have now decided to join it by making Excel a possible client that works with the rest of their software (Watson 2009). From the Business Intelligence Framework (Watson and Wixom, 2007), Excel is used in both getting data in and getting data out. According to Microsoft (2019), Excel has a number of power tools (such as PowerQuery, PowerPivot, PivotTables, functions and formulas) for data extraction, transformation, loading and analytics. However, when using Excel, the data extraction and transformation are performed as one step.

Using Power Query, data can be extracted from different sources such as file, online data warehouse, web and databases. The Power Query also provides transformations features which combines and shapes data from different sources to meet user needs. Using Power Pivot, the models with relationships between tables are created. Its features of powerful analysis and creation of interactive dashboards and reports position Excel as a very capable tool in the getting data out activity. For enterprise reporting, Excel offers tools to create dashboards that make it easy to perform quick overviews rather than going through large volumes of data.

To achieve the maximum use of Excel as BI tool, users need to have certain advanced skills. In this paper, a skill is taken as an ability to perform a data process task using Excel tools in a competent manner. Users require advanced skills particularly in data extraction from different sources, transformation using power tools and formulas, and analytics.

3   Methodology

The study adopted the qualitative case study approach with the aim of understanding accountants within their working context. This provides a deeper understanding of the phenomenon under investigation (Yin, 1994). The authors employed the deductive approach in which data was collected based on the BI framework illustrated in Figure 1. The case study took place in a corporate institution setting where the authors collected data in two corporate companies; one was a private company and another one was a statutory corporation. Both corporate institutions are comparable sizes in terms number of employees and asset base. They are treated as one case. In this paper, the first company is referred to as *Corporate A* and the second one as *Corporate B*. Both corporate companies generate volumes of data from different sources which their respective accountants manipulate using Excel. The case study helped the authors in gaining a rich understanding of Excel skill gaps among accountants. The case study data was gathered in 2020 mainly through participant observations and artefact examination, which were supplemented by semi-structured interviews.

3.1   Participant Observation

The first and second authors participated in five Excel training sessions as the key trainers involving 60 trainees in total who ranged from junior accountants, senior accountants, supervisors to financial managers. The trainees were graduates with work experiences ranging from 3 months to over 11 years in accounting and finance. Three training sessions were conducted in the trainees' workplaces (Corporate A) while two training sessions were at a training institution (Corporate B). The authors

were involved in training design, content development, training and documentation. The training content ranged, for example, from basic Excel skills in basic formulas and function, navigation, cell referencing, formula auditing, data validation, and sorting and filtering to advanced skills in pivot tables and charts, slivers and time lines, power functions and text functions, nested if functions, macros, and what-if and sensitivity analysis.

3.2   Artefact Examination

All three authors examined Excel features for BI and financial datasets from the trainees that were used in the training sessions. The third author, as independent reviewer, examined artefacts such as training programmes, training content, referencing materials, and training reports that were developed with interventions of the first two authors. The third author has not participated in any way in the training programme design and sessions. The artifact examination enabled the authors to obtain the witness of past events and to identify some areas that needed further investigation.

3.3   Semi-structured Interviews

The first two authors conducted semi-structured group interviews during the training sessions in three stages. The first interviews were with the trainees at the beginning of individual training sessions for two hours in order to get general view on the trainees' expectations and basic Excel knowledge. The second interviews were conducted on daily basis after training for one hour to get views from the trainees on the training delivery and content. The third interviews were conducted at the end of each training session for two hours to get final feedback from the trainees. During interviews, the note-taking technique was used and immediately after the interviews, data transcription was done.

3.4   Data Analysis

The authors were collecting and analysing data concurrently and being guided by the BI framework (Figure 1) which allowed them to remain open to new insights that might emerge. The authors analysed data through four steps: immersion in the data, coding, category creation, and theme identification (Green et al., 2007), which were not done in a linear fashion; rather, moving back and forth through the processes in order to make sense of the whole dataset. This allowed authors to systematically integrate new data into the analysis and assess relevance of chosen theoretical concepts as the data analysis proceeded (Green et al., 2007).

4   Findings and Discussions

The findings are presented and discussed in alignment with the two-part process of BI: getting data in and getting data out (see Figure 1).

4.1   Business Intelligence (BI) in Excel

It has been observed that users can perform BI in Excel in two ways: by using Vanilla Excel and Power tools (as referred to in this paper).

4.1.1   Using Vanilla Excel

In this paper, Vanilla Excel is defined as using Excel without Power tools such as Power Query and Power Pivot. In the context of getting data in and getting data out, Vanilla Excel can be used at the low scale as illustrated in Figure 2. For instance, the step A and B are the

getting data in tasks while the step D is the getting data out tasks. The step C handles both getting data in and getting data out.
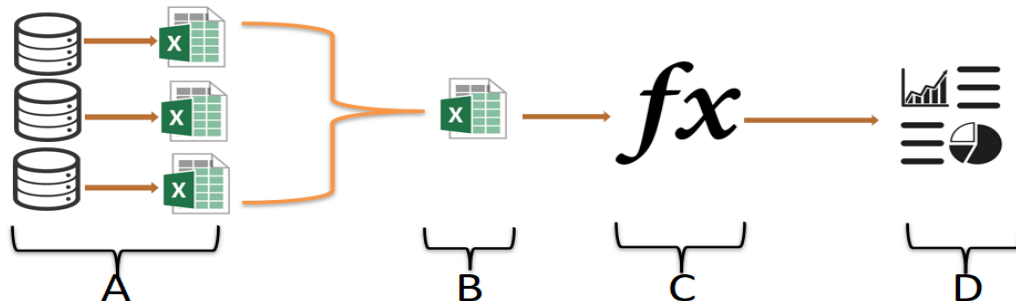
Figure 2: Business Intelligence in Excel using Vanilla Excel

Using Vanilla Excel, usually, data is extracted from enterprise databases and then analyzed using Excel. However, before the analysis is done, the data is transformed into a model that is used to create reports and dashboards. The steps in Figure 2 are summarised below.

- A – In this step, data is extracted from different sources as Excel files.
- B – Then the extracted Excel workbooks can be combined into one Excel workbook.
- C – In this step, data is cleaned and transformed to form a model. This involves the use of different Excel functions such as text functions, lookup functions and power functions.
- D – This is the part of Getting data out in which different reports and dashboards are created. Excel provides different tools for reporting such as charts, slicers, pivot tables, pivot charts, sparklines, and timelines.

4.1.2   Using Power Tools

To empower Excel as BI tool, power tools such as PowerQuery and PowerPivot were introduced in recent versions of Excel (e.g. Excel 2016, 2019) resulting in using Excel to handle multiple sources and large volumes of data as compared to Vanilla Excel. For instance, PowerQuery provides connections from different sources such as file, databases, data warehouse, and data lakes. PowerPivot empowers Excel to handle big data.

4.2   Getting Data In and Getting Data Out

As illustrated in Figure 1, the getting data in involves extraction, transformation and loading of data (ETL). It has been observed that the accountants usually adopt the Vanilla Excel due to the level of Excel skills as one participant pointed out: "Before this training, I had no knowledge on how to use these power tools and advanced formulas … this is fantastic."

4.2.1   Data Extraction

It has been observed that the accountants get data from different sources including business enterprise databases. Business enterprise databases have facilities which allow the

accountants to export data into Excel. Even data used in the training sessions were exported from business enterprise databases. From a single business enterprise database, however, all required data is extracted into a single Excel sheet from which individual accountants can now extract specific data that he/she wants to analyse. This data is presented in different small Excel files representing individual business enterprise units.

In most cases, the small sheets need to be integrated with Excel sheets having data from other sources including external ones. The observation is that instead of having the data warehouse holding all required data from different sources ready for the data analysis (Nowicki et al., 2007; Watson and Wixom, 2007), the accountants have a number of Excel files that require to be integrated. However, most accountants do not know how to integrate Excel workbooks. Instead, for example, pre-defined Excel worksheets with formulas and functions are prepared and integrated with other worksheets in which the accountants only change data values. One participant commented: "We are told not to change anything in these given worksheets … we only change data in our own extracted worksheets." Having a number of Excel files brings challenges in the data transformation that is also critical in the getting data in.

4.2.2   Data Transformation

Two key challenges, data incompleteness and formatting, have been identified during the data transformation. The data incompleteness happens due to two reasons. Firstly, in the extracted data from business enterprise databases, some columns are missing and hence the accountants need to create new columns and manually capturing required data which in most cases come from the individual accountant's memory. This means that if the accountant is a new user, it will be a problem to define missing data. Secondly, sometimes it happens that data extracted from external sources are not available that makes data to be incomplete. Since this data is from external sources, there is nothing the accountants can do. To effectively perform business intelligence, one factor for data to be completely transformed is replacing the missing data (Watson and Wixom, 2007); otherwise data analysis will not be possible.

Changing of column data formats is another factor for the effective business intelligence (Watson and Wixom, 2007). However, it is another key challenge with the accountants during the data transformation. The accountants have been failing to convert data from one format to another because of how extracted data is presented in Excel. For example, some data have hidden special characters that need users to identify appropriate functions for data cleaning. However, most accountants had no adequate knowledge on Excel functions. Instead, the accountants have been forced to create new columns and manually re-enter the values with right formats. Although addition and removal of columns are some activities in data transformation (Watson and Wixom, 2007), it is not a good practice to create new columns for manual data capturing every time when the accountants fail to format data. The manual data capturing is also determined by data inconsistence in terms of properties such as length. In this case, multiple advance format functions are to be used.

To minimise the manual data capturing, the accountants need to use advanced Excel format functions. For instance, in some cases, the accountants need just to use the SUBSTRING function to extract some characters in a column instead of manually capturing them in a new column. In other cases, they can use advanced functions such as SUBSTITUTE to remove

unnecessary characters that hinder data values to be formatted accordingly. However, it has been observed that the accountants have no adequate skills to use such functions to perform complex formatting.

4.2.3   Data Loading

As stated earlier, after transformation, data is to loaded into a data warehouse or mart for generation of insights for decision making (Watson and Wixom, 2007). However, using Vanilla Excel as observed in this study, data loading part of the getting data out is incorporated in the data extraction.

4.2.4   Data Analytics

In data analytics, Excel skill gaps for the accountants are mainly related to pivot tables, advanced functions, and dashboards. Pivot tables are one crucial facility in data analytics that manipulate data in terms of, for example, summarization, reorganization, grouping, counting and even advanced calculations. It has been observed that the accountants have not had adequate knowledge on the meaning of pivot tables although they were able to create pivot tables with basic features. The practice has been that they created pivot tables for each small Excel files instead of the original single file. One participant appreciated: "We did not know that it is possible to create pivot tables from one large Excel file … we have now detailed insights." In addition, they have had no skills in the calculated fields that create a value to the existing data. The lack of knowledge in pivot tables has also affected in the creation and interpretation of pivot charts since the pivot chart is the visual representation of a pivot table.

In data analysis in Excel, functions are important for data manipulation. The accountants have demonstrated during the training sessions that they have had adequate knowledge and skills in basic Excel functions such as SUM, AVERAGE and COUNT but not advanced functions like conditional, lookup and nested functions. This lack of skills in advanced functions has also contributed to failing to handle errors when using pre-defined worksheets. One participant commented: "Since we have not known what to do when error occurs in these worksheets … after this training we will possibly analyse advanced formulas and functions."

It has also been observed that the accountants were not confident with dashboards and visualisation as one participant emphasised: "I have been wondering how my colleagues are able to view their data in fashionable ways." Excel dashboards help users in tracking key KPIs or metrics and take informed decisions and data is presented as charts, tables, and views. The accountants need adequate knowledge and skills on slicers and timelines (as filters to pivot tables and charts) and macros in order to create interactive dashboards.

5   Conclusion and Recommendations

It has been observed that corporate institutions in Malawi extensively use Excel for business analytics, particularly amongst accountants. Despite its importance and extensive usage, many accountants lack adequate Excel skills to get most out of Excel. Particularly, skills related in data extraction, transformation and analytics. Although they use Excel on daily basis for analysis using basic functions and features, they lack advanced skills in Excel power tools that are needed for BI. Hence,

they are not able to make the appropriate business analysis needed for decision making. It is therefore important that Excel skills be at the heart of the business' human resource.

The authors recommend that the following should be done in order utilise Excel for Business Intelligence in the corporate institutions in Malawi:

1) Due to the skill gap for the new recruits, the institutions should make sure that the new recruits are given Excel skills as part of their recruitment process. For those already working in the institutions, they need to undergo advanced Excel trainings that should cover the use of Pivot tables, Pivot Charts, conditional functions, and Power tools such as Power Query, Power Pivot, Power View, and Power Map for Business Intelligence.
2) The authors also recommend that institutions (or companies) should work towards having warehouse solutions or data marts that will link to the company's source systems. Data warehouse or data marts allow for the standardization of the data making it ready for analysis in Excel or something equivalent either on premise or cloud for better business analysis.

The next step for the authors is to carry out research that focusses on the use of other BI tools other than Excel among large number of corporate institutions in Malawi.

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Examining the Relationship Between Enterprise Resource Planning (ERP) Implementation: The Role of Big Data Analytics Capabilities and Firm Performance

Abstract

Enterprise Resource Planning (ERP) implementation continues to hold attraction from information systems enthusiasts. Perhaps due to the rising budget dedicated to the implementation in many an organization in recent times. However, understanding the critical role that ERP implementation plays in Big Data Analytics Capabilities and firm performance is lacking sufficient treatment in the literature. By applying quantitative research techniques in a case study research orientation through the use of resource-based view theoretical insights, the study takes on three key hypotheses: That ERP implementation has a positive relationship with organizational big data analytics capabilities; Big data analytics capability has a positive effect on firm performance and ERP implementation is positively related to organizational performance. Using Partial Least Squared Structural Equation Model (PLS-SEM) data analysis techniques the study established a direct link between big data analytics capabilities and firm performance, and that ERP has a direct positive and significant effect on big data analytics capabilities. Lastly, it is the claim of this study that big data analytics capabilities have a direct positive and significant effect on firm performance. Part of the implications of the study highlights the need for a qualitative or even mixed method research undertakings to broaden the frontiers of our understanding in terms of ERP implementation and big data analytics capabilities in similar organizational contexts.

1. Background

For organizations to survive in today's competitive business environment, the application of creative and innovative ideas and strategies become essential (Al-Dhaafri, Al-Swidi, and Yusoff, 2016). Following the benefits of IS as touted by professionals and scholars alike (Shang and Seddon, 2000; Staehr, Shanks and Seddon, 2012; Althunibat et al., 2019), several organizations have decided to invest in the adoption of Enterprise Resource Planning (ERP) to enhance their business processes and improve their performance. The study focuses on organizations with ERP implementation experience. The subject of interest in this case is manufacturing and service organizations. The essence of this subject of interest is to develop a research model that validates primary data collected from firms in Kumasi and Accra. The choice of Kumasi and Accra is because of its geographical proximity and also due to the fact these two cities are have a number of large organizations that are heavily involved with the implementation of ERP systems in recent times.

The Enterprise Resource Planning (ERP) is an information system helps firms to achieve their need for an integrated organization (Madapusi and D'Souza, 2012; Rupa, Rao and Babu, 2019; Shah et al., 2011). ERP has been in existence for over 30 years and its adoption within organizations continues to increase (Eker and Aytaç, 2016).

Many have touted the favourable uses of ERP systems as aiding the solution of the challenges in business systems fragmentation (Kashani, 2014) that results in duplication of information, data redundancy and difficulty in information sharing across the organization. The integrative nature of ERP allows organizations to enhance its information processing, decision making and innovation capabilities (Ram, Corkindale and Wu, 2014). With the innovation capabilities, the advent of social media and cloud computing systems have seen the trend for firms to integrate their ERP systems with social media and move their ERP-applications and databases into the cloud (Gupta, Qian, Bhushan and Luo, 2019).

Large volumes of diverse data sets entering an organization at an increased speed is referred to as big data (Gandomi, and Haider, 2015). Akter et al. (2016) also explains that big data analytics capability refers to the ability to manage big data for useful business insights. While ERP implementation has the prospect to enhance big data analytics capabilities of organizations, some studies have acknowledged that big data capability plays a key role in improving the performance of organizations (Akter et al., 2016). The study hypothesizes the point that ERP implementation has a direct positive effect on organizational big data capabilities and also firm performance. Again, the study hypothesizes the idea that big data analytics capabilities has a direct positive effect on firm performance and also mediates the relationship between ERP implementation and firm performance.

Madhani (2009) contends that distinguishing between sources that offer success and those that provide sustainability is very challenging. Therefore, it is necessary to make a significant managerial effort to identify, classify, and understand these resources that offer core competencies, sustainability, and competitive advantage. In view of this, the resource-based view theory is applied to tease out the ideals of this study. Drawing on this theory, this study specifically examines the direct effect of ERP implementation on organizational Big Data capabilities. In doing this, the study explains how well ERP implementation affects BDA capabilities and performance of organizations. In addition, this research aims to examine the effect of ERP implementation on organizational big data analytic capabilities, ascertain the effect of ERP implementation on firm performance and determine the effect of big data analytics capabilities on firm performance. Doing

this is designed to make some contribution to not only knowledge but also in terms of practice. This claim is grounded in the call to address the mechanisms by which ERP implementation influence firm performance through the examination of the link between ERP implementation, BDA capability and the performance of firms (Al-Dhaafri et al.'s 2016; Elragal's 2014).

The rest of the paper proceeds as follows. After this introduction, the next section reviews the contemporary account on ERP systems in terms of both their theoretical and practical perspectives. The methods that guided the study comes next with the sampling techniques as wells the design approach that motivated the sampling techniques for data collection and analysis. Findings from the study are presented for analysis and research implications are briefly discussed to conclude the paper.

2. **ERP Implementation and Big Data Analytics**

The ERP has been developed through the growth and expansion of the Manufacturing Resource Planning (MRP II) and the Material Requirement Planning (MRP) (Abdullah 2017; Elmes et al., 2005). In the 1980s, MRP evolved from control and material planning to a firm-wide program capable of planning and controlling almost all organizational resources (Chen, 2001; Miclo et al., 2017; Soja, 2008). MRP progressed even more towards ERP in the 1990s (Akkermans et al., 2003; Bahssas, AlBar, and Hoque, 2015; Chen, 2001). ERP is a dynamic and unpredictable exercise that has led to a range of glitches, unfulfilled incentives, budget overruns and less than completely used systems (Alsayat and Alenezi, 2018; Saeed et al., 2017). A dominant aspect of the literature on the topic therefore deals with the problems of success in implementation and other related matters (Alsayat and Alenezi, 2018; Garg and Garg, 2013; Motiei et al., 2015; Narayanamurthy and Gurumurthy, 2017; Saeed et al., 2017; Zerbino et al., 2017). The major advantage expected from any ERP is the lower cost of IT infrastructure and human capital (Gattiker and Goodhue, 2004; Holsapple and Sena, 2005; Madanhire, and Mbohwa, 2016).

The concept of large data also serves to define in real time large and complex, unstructured, semi-structured and structured data, requiring sophisticated management, analysis and processing methods, which offer your insight (Fosso Wamba et al., 2015). Big data has been one of the main technological disruptors since the arrival of the Internet and the digital economy (Agarwal and Dhar, 2014) because of the high data volumes, data diversity, advanced storage, management, analysis and visualization techniques are essential (Chen et al., 2012).

Big data includes high speed data collection and sensor data for real-time analytical data (Chen et al., 2012). Big-data analytics, according to Jeble et al. (2017), consist of a structured method in which market data are obtained and analyzed, mathematical models are designed to describe the (descriptive) phenomenon, a model is built to forecast future outcomes using variable inputs (Predictive Analysis), and a model is designed to optimize or related input variations (Prescriptive Analytics). It uses statistical techniques for the creation of equations, such as simulation, factor analysis, multivariate statistics and mathematical knowledge (Dubey and Gunasekaran, 2015).

The majority of large-scale data investments are not rewarding because most businesses are not ready to make decisions in response to the information derived from data, (Ross, Beath and Qaadgras 2013). McAfee and Brynjolfsson (2012) stress the value of a culture of decision-making based on data, as senior managers take decisions based on data instead of their intuition. Management failure is often listed as a key factor in the performance of Big Data initiatives (LaValle et al., 2014).

The success of large-scale data projects is not only the result of data and analysis, but also includes a wide range of aspects (Garmaki et al., 2016). To solve this problem, the concept of big data analysis has been established (Mikalef et al., 2017). In general, the capacity of big data analytics is defined as a company's ability to provide insights through data management, technology and expertise, which make it competitive (Kiron et al., 2014; Act et al. 2016). The dimensions of big data analytics capability are discussed below:

Gupta and George (2016) conceptualized data as a dimension of big data analytics capabilities. Manyika et al. (2011), expound that in addition to labour, capital, and land, a number of organizations now consider data as a key factor of production. On the contrary, George et al. (2014), recognise five sources of big data as public data; private data; data exhaust; community data; and self-quantification data. Private data refers to firm-owned data that are actively collected by the firms (George et al., 2014; Gupta and George, 2016). Data exhaust refers to the data that do not have a direct value attached to them but can be combined with other sources to yield new insights (George et al., 2014; Gupta and George, 2016). Zhao et al. (2014) broadly classify data into in two types: internal data (data emanating from a firm's internal operations of an organization); and (ii) external data (data emanating from a firm's interaction with external actors. In furtherance Gupta and George (2016) make the claim that a firm's ability to integrate internal and external data creates big data capabilities.

The second dimension of big data analytics capabilities identified by Gupta and George (2016) is technology. Gupta and George (2016) argue that some advance technologies are required to handle the challenges posed by gigantic, diverse, and fast-moving data as occurs in recent times.

3. Resource-Based View

The resource-based view is a theory that has been applied severally by different scholars to explain the mechanism through which organizations attain superior performance and competitive advantage (Dubey et al., 2019; Gupta et al., 2018; Huo et al., 2016; Popli et al., 2017; Yu et al., 2018). From a managerial perspective, the resource-based view emphasizes the managerial efforts aimed at attaining market advantages that are sustainable and allows firms to generate super normal profits (Ali et al., 2016; Anvar, 2017; Bowman and Toms, 2010; Carter et al., 2017). According to Akter et al. (2016) the resource-based view counts on two main assumptions about organizational resources to reveal why some organizations do better than their rivals. First, for every organization in the same industry, the resource possessed by each firm varies (Peteraf and Barney, 2003). Second, the differences in resources held by various organizations are facilitated by the challenge of sharing resources across organizations. In addition to the two assumptions stressed by Atker et al. (2016), a resource-based perspective is emphasized in the **Valuable, Rare, Imperfectly imitable, Organized** context. The VRIO Resource-Based View Theory explains that the success of an organization depends on the degree to which the resources kept by the organization are valuable (V), rare(R), imperfectly imitable(I) resources properly organized(O) (Amit and Schoemaker,1993; Barney et al., 2001). Second, the valuation of resources allows a company to raise net profits and reduce net costs, which in other words, lets businesses capitalize on opportunities and mitigate the hazard (Barney and Arikan, 2001; Barney and Hesterly, 2012). Secondly, the unique aspect means that a few firms will achieve competitive advantages. Thirdly, the imperfectly aspect means, since it is expensive to mimic, that businesses cannot duplicate or substitute such methods directly. Research shows that the complementarity of capital within an organization renders replication impossible for competitors (Morgan et al., 2009). Finally, the

organization, in order to optimize its full competitive efficiency, concentrate on the effective management of essential rare and imperfectly emulated resources (Barney and Clark, 2007). Again, based on the resource-based view theory, this study proposes that conceptual framework model below:
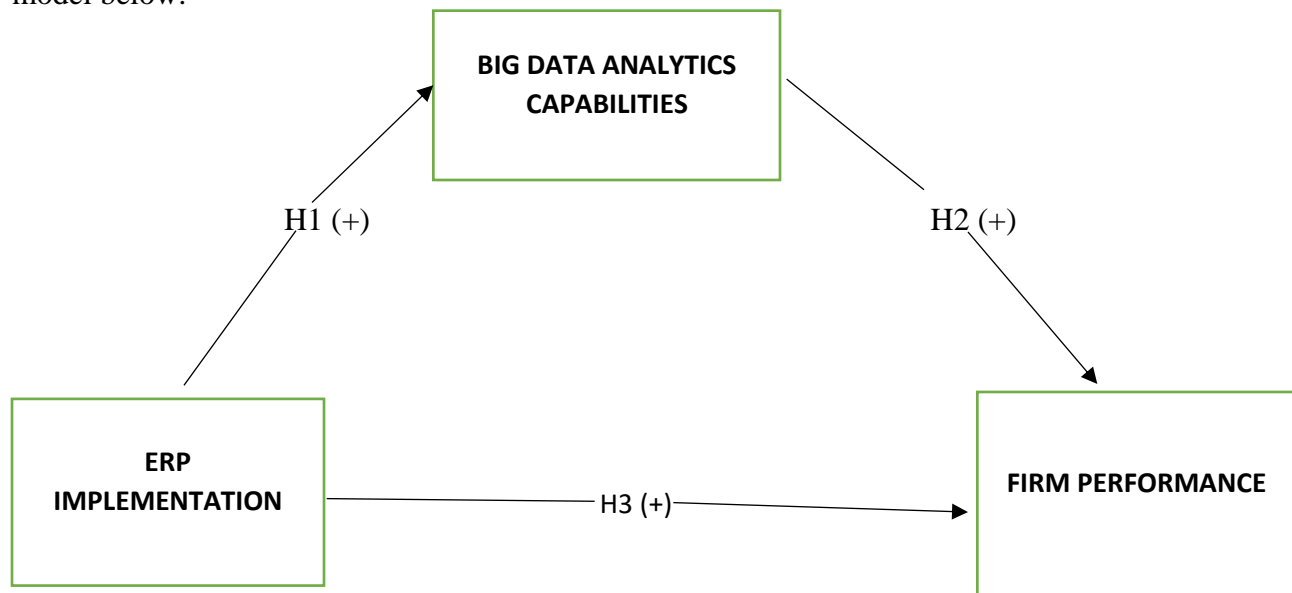
Figure 1: Conceptual framework

3.1 The Relationship between ERP Implementation and Big Data Analytics Capability

Companies are improving their ability to generate competitive advantages by using organizational tools like ERP system to build specific and evolving skills to meet client needs and to adapt to competition challenges (Teece et al., 1997). ERP systems have a huge influence on corporate capability (Masini and van Wassenhove, 2009).
Therefore, this study postulates that:

H1: ERP implementation has a positive relationship with organizational big data analytics capabilities.

3.2 The relationship between Big Data Analytics Capability and Firm Performance

The ability to analyze large data plays a major role, particularly in changing market performance (Akter et al., 2016; Wamba et al., 2017). Some current studies have found that the organizational big data analytics and company results are in a positive relationship (Schroeck et al., 2012; Wamba et al., 2017). In view of this study postulates that:

H2: Big data analytics capability has a positive effect on firm performance.

The relationship between ERP Implementation and Firm Performance

Real-time information and automation enabled by ERP systems helps firms to reduce cost in numerous ways (Ali, van Groenendaal and Weigand, 2020). Some studies looked at the correlation between ERP implementation and corporate performance. Again, a report by Hunton et al. (2003) reaffirmed that the performance of companies adopting ERP was superior to the performance of their peers in the form of investments return, and asset revenue as corporate performance indicators. Accordingly, this study hypothesizes that:

H3: ERP implementation is positively related to organizational performance.

4. Methods and Model Analysis

This research applies the quantitative philosophical assumptions as a mode of analysis of the collected data. Drawing on Leavy (2017), the quantitative approach is mostly used for empirical validation of theories and the determination of the relationship between ERP implementation and BDA capability makes the quantitative technique a most feasible sense. The feasible approach stems from the fact that it involves the use of statistical tools to analyse data for trends, correlations and causal relationships (Cresswell, 2014). The study applied the PLS-SEM technique to analyze the research model the various hypothesized paths. The SmartPLS version 3 was employed (Ringle et al., 2015). When using the PLS-SEM technique, two stages of analysis are required. The first stage involves the test of the measure model and the second stage involves the test of the structural model (Hair et al, 2017).

The primary objective of the study of the metrics model is to determine the reliability and validity of the research model (Hair et al., 2019). The measuring model evaluates the correlation between a latent variable and its indicators. The test of the measuring model ensures that each object tests its variable accordingly. The two key criteria used in testing the measuring model are convergent validity and discriminating validity (Hair et al., 2010; Ramayah et al., 2011). The measurement model assessment began with a test of convergent validity. According to Hair et al. (2017), convergent validity is the extent to which a measure relates to the measures of the same variable. In this study, convergent validity was assessed using the psychometric properties of the variables (Hair et al., 2014). The psychometric properties assessed in this study were Cronbach's alpha, Composite reliability, rho A, and Average variance extracted. This test was necessary to ensure that each of the psychometric properties meets their required threshold (Hair et al., 2019).

The cronbach's alpha, tests the correlation among the indicators of a latent variable, and a benchmark of 0.7 and above is recommended (Chin, 1998; Hair et al., 2010). From Table 1.2, all constructs have Cronbach Alpha values larger than 0.7. Composite reliability on the other hand measures the capacity of the indicators to explain the variance of their latent variable, with a proposed benchmark of higher than 0.7 (Chin, 1998). Again, from Table 1.2, all constructs have composite validities higher than 0.7. Average Variance Extracted (AVE) is the grand mean value of the squared loadings of a set of indicators and is equivalent to the communality of a construct, with a recommended threshold of greater than 0.5 (Hair et al., 2014). All constructions comply with this condition as can be seen in Table 1.2. The Rho_A has recently emerged as an important measure of reliability for PLS-SEM and is currently the only reliable measure of reliability for PLS build scores, with a minimum rho A value of 0.7 suggested by (Dijkstra and Henseler, 2015). Again, all constructs exceeded the recommend threshold as can be seen from Table 1.2.

The study used the online questionnaire which was developed using Google formats and controlled through emails and social media platforms. During the project, 120 respondents received approximately 82 responses. In order to avoid false data, the 82 answers were tested. On the basis of the sampling, 8 answers have been excluded, with 74 analytical replies remaining. Therefore, the study obtained a 61.66 percent response rate. And it is made of 74 reactions obtained.

The demographic characterization of the respondents is provided in this section. SPSS was used to evaluate the demographic profiles of interviewees. Statistical methods were used, including frequency and percentages. Information about the demographic features of the interviewees is shown in detail in Table 1.1 below.

Table 1.1: Demographics

	Responses	Frequency	Percent
State run Enterprise	Yes	16	21.6
	No	58	78.4
How long has your firm been in operation	less than 1 year	5	6.8
	1-2	8	10.8
	2-3	12	16.2
	3-4	8	10.8
	4-5	3	4.1
	5-10	14	18.9
	Above 10	24	32.4
How long have you worked in the company	Less than 1 year	5	6.8
	1 to 3 years	23	31.1
	3 to 5 years	33	44.6
	Above 5 years	13	17.6
Employee Size	Less than 6	18	24.3
	6-29	9	12.2
	30-59	10	13.5
	60-99	10	13.5
	100 +	27	36.5
Ownership of company	Solely Ghanaian Owned	50	67.6
	Foreign Owned	9	12.2
	Joint	15	20.3
Legal form of Entity	Sole Proprietorship	29	39.2
	Partnership	16	21.6
	Limited Liability	16	21.6
	Public Limited Liability	9	12.2
	State owned	4	5.4
	SAP	19	25.7

Which of the following ERPs is used by your organization?	Oracle	10	13.5
	Microsoft Dynamics	43	58.1
	JD Edwards	2	2.7
Education	Undergraduate	38	51.4
	Masters	26	35.1
	PhD	3	4.1
	Certificate/Vocational/Professional	7	9.5
Revenue	< 10,000	16	21.6
	10,0000-30,000	14	18.9
	30,001-100,000	9	12.2
	100,001 –500,000	3	4.1
	500,000 – 1,000,000	8	10.8
	>1,000,000	24	32.4
Company's corresponding industry	Manufacturing	15	20.3
	Financial Services (banking & investments)	6	8.1
	Health	7	9.5
	Retail	12	16.2
	Construction	10	13.5
	Transportation	5	6.8
	Telecommunication	4	5.4
	Electronics and Computing Machinery	6	8.1
	Mining & Minerals	2	2.7
	Agribusiness	7	9.5
	Total	**74**	**100.0**

Table 1.2 Psychometric Properties of the Constructs

Variables		Cronbach's Alpha	rho_A	Composite Reliability	Average Variance Extracted (AVE)
Big Data Analytics Capability	Data	0.861	0.863	0.915	0.783
	Data Driven Culture	0.738	0.741	0.835	0.558
	Management	0.921	0.923	0.941	0.761
	Organizational Learning	0.82	0.826	0.882	0.652
	Personnel	0.852	0.856	0.9	0.693
	Basic Resources	0.948	0.95	0.966	0.905
	Technology	0.827	0.838	0.885	0.658
	ERP	0.96	0.965	0.964	0.644
	Firm Performance	0.937	0.941	0.947	0.666

Table 1.3: Item Loading

	BCDA	BCDDC	BCMGT	BCOL	BCPS	BCRES	BCTCH	ERP	FP
BCDA1	0.914								
BCDA2	0.887								
BCDA3	0.853								
BCDDC1		0.762							
BCDDC2		0.701							
BCDDC4		0.794							
BCDDC5		0.728							
BCMGT1			0.894						
BCMGT2			0.876						
BCMGT3			0.902						
BCMGT4			0.864						
BCMGT5			0.825						
BCOL1				0.728					
BCOL2				0.858					
BCOL3				0.873					
BCOL4				0.76					
BCPS1					0.785				
BCPS2					0.862				
BCPS3					0.84				
BCPS4					0.842				
BCRES1						0.954			
BCRES2						0.931			
BCRES3						0.969			
BCTCH1							0.868		
BCTCH2							0.807		
BCTCH3							0.736		
BCTCH4							0.829		
ERP1								0.733	
ERP10								0.898	
ERP11								0.875	
ERP12								0.795	
ERP13								0.874	
ERP14								0.724	
ERP15								0.865	
ERP2								0.802	
ERP4								0.765	
ERP6								0.794	
ERP7								0.801	
ERP8								0.878	
ERP9								0.802	

FPMP1		0.803
FPMP2		0.785
FPMP3		0.849
FPMP4		0.855
FPOP1		0.736
FPOP2		0.8
FPOP3		0.826
FPOP4		0.837
FPOP5		0.845

Discriminant validity

Discriminatory validity guarantees that the concept of construct measures is empirically unique and that other measures in a structural equation model do not capture phenomena of interest (Hair et al., 2010). In this analysis, the discriminatory validity was evaluated using three techniques: The Fornell-Laker criteria, Cross-loading products and Heterotrait-Monotrait correlation ratio (HTMT) The Fornell-Larker criterion suggests that there is discriminatory validity when the square root of the AVE of the factor is greater than its correlation with all other variables in the model (Fornell and Larcker, 1981). In Table 1.4 below the diagonal values in bold indicate the square root of the construct AVE, while the off-diagonal values represent the interrelation between the constructs. Table 4.4 shows that all diagonal variables are greater than off-diagonal values, confirming discriminant validity of the model.

Table 1.4: Fornell-Larker Criterion

	BCDA	BCDDC	BCMGT	BCOL	BCPS	BCRES	BCTCH	ERP	FP
BCDA	0.885								
BCDDC	0.584	0.747							
BCMGT	0.682	0.437	0.873						
BCOL	0.465	0.556	0.418	0.807					
BCPS	0.685	0.602	0.719	0.561	0.833				
BCRES	0.717	0.505	0.774	0.367	0.715	0.951			
BCTCH	0.729	0.556	0.751	0.422	0.665	0.839	0.811		
ERP	0.622	0.531	0.527	0.27	0.513	0.537	0.565	0.821	
FP	0.742	0.545	0.612	0.523	0.65	0.63	0.708	0.581	0.816

The technique of cross loading suggests that when no research item loads other buildings more than their own, it is discriminating in validity (Hair et al., 2014; Barclay et al., 1995). All items with high cross loads have been dropped according to recommendation (Hair et al., 2012). After all measurements were dropped, the validity of the research model was confirmed in Table 4.5 as all items loaded higher onto their own constructions than on other buildings.

Table 1.5: Cross Loading

	BCDA	BCDDC	BCMGT	BCOL	BCPS	BCRES	BCTCH	ERP	FP
BCDA1	0.914	0.548	0.622	0.45	0.684	0.654	0.632	0.562	0.682
BCDA2	0.887	0.534	0.587	0.469	0.607	0.547	0.615	0.571	0.615
BCDA3	0.853	0.468	0.601	0.313	0.523	0.701	0.691	0.541	0.673
BCDDC1	0.439	0.762	0.301	0.401	0.363	0.28	0.405	0.313	0.429
BCDDC2	0.35	0.701	0.291	0.122	0.32	0.43	0.408	0.432	0.285
BCDDC4	0.535	0.794	0.239	0.494	0.421	0.386	0.416	0.377	0.404
BCDDC5	0.413	0.728	0.448	0.577	0.641	0.409	0.43	0.432	0.482
BCMGT1	0.604	0.456	0.894	0.368	0.702	0.695	0.573	0.451	0.447
BCMGT2	0.549	0.368	0.876	0.373	0.716	0.739	0.615	0.434	0.43
BCMGT3	0.696	0.391	0.902	0.558	0.7	0.662	0.634	0.441	0.561
BCMGT4	0.545	0.322	0.864	0.272	0.494	0.652	0.731	0.495	0.614
BCMGT5	0.573	0.364	0.825	0.229	0.506	0.626	0.736	0.443	0.629
BCOL1	0.305	0.419	0.364	0.728	0.319	0.204	0.325	0.197	0.432
BCOL2	0.39	0.528	0.383	0.858	0.454	0.312	0.431	0.38	0.55
BCOL3	0.347	0.356	0.282	0.873	0.435	0.236	0.246	0.136	0.331
BCOL4	0.438	0.466	0.312	0.76	0.574	0.402	0.337	0.168	0.355
BCPS1	0.553	0.528	0.521	0.455	0.785	0.591	0.582	0.412	0.491
BCPS2	0.653	0.537	0.628	0.407	0.862	0.688	0.685	0.478	0.628
BCPS3	0.535	0.482	0.615	0.493	0.84	0.52	0.423	0.441	0.488
BCPS4	0.531	0.456	0.627	0.522	0.842	0.571	0.508	0.4	0.544
BCRES1	0.697	0.508	0.735	0.336	0.718	0.954	0.828	0.499	0.603
BCRES2	0.628	0.422	0.717	0.307	0.581	0.931	0.78	0.502	0.546
BCRES3	0.717	0.506	0.756	0.4	0.735	0.969	0.786	0.523	0.645
BCTCH1	0.693	0.513	0.642	0.283	0.546	0.777	0.868	0.462	0.693
BCTCH2	0.431	0.421	0.542	0.16	0.436	0.612	0.807	0.493	0.486
BCTCH3	0.586	0.391	0.583	0.396	0.481	0.475	0.736	0.491	0.461
BCTCH4	0.628	0.469	0.655	0.502	0.665	0.811	0.829	0.407	0.624
ERP1	0.428	0.312	0.285	0.203	0.209	0.17	0.192	0.733	0.299
ERP10	0.564	0.512	0.483	0.354	0.472	0.455	0.53	0.898	0.576
ERP11	0.537	0.429	0.557	0.204	0.482	0.556	0.571	0.875	0.564
ERP12	0.42	0.323	0.353	0.111	0.364	0.442	0.466	0.795	0.359
ERP13	0.463	0.42	0.454	0.146	0.418	0.496	0.545	0.874	0.559
ERP14	0.41	0.38	0.468	0.138	0.295	0.454	0.468	0.724	0.409
ERP15	0.5	0.42	0.496	0.117	0.402	0.574	0.559	0.865	0.473
ERP2	0.487	0.502	0.486	0.212	0.422	0.455	0.425	0.802	0.41
ERP4	0.585	0.453	0.304	0.354	0.423	0.304	0.321	0.765	0.419
ERP6	0.585	0.422	0.3	0.449	0.477	0.37	0.423	0.794	0.541
ERP7	0.648	0.516	0.399	0.282	0.447	0.393	0.45	0.801	0.555
ERP8	0.575	0.559	0.524	0.224	0.495	0.481	0.491	0.878	0.502
ERP9	0.381	0.35	0.446	0.031	0.475	0.481	0.47	0.802	0.403

FPMP1	0.497	0.433	0.519	0.503	0.532	0.494	0.553	0.445	0.803
FPMP2	0.607	0.493	0.44	0.345	0.439	0.536	0.51	0.493	0.785
FPMP3	0.705	0.545	0.553	0.349	0.561	0.668	0.689	0.635	0.849
FPMP4	0.581	0.542	0.545	0.332	0.525	0.609	0.703	0.628	0.855
FPOP1	0.546	0.363	0.504	0.431	0.574	0.53	0.469	0.342	0.736
FPOP2	0.605	0.404	0.475	0.48	0.513	0.357	0.488	0.491	0.8
FPOP3	0.638	0.388	0.414	0.535	0.509	0.392	0.538	0.411	0.826
FPOP4	0.594	0.412	0.612	0.487	0.603	0.575	0.669	0.408	0.837
FPOP5	0.674	0.387	0.397	0.413	0.507	0.405	0.521	0.445	0.845

The final test of discriminant validity was the HTMT test. HTMT is the average of the correlations of indicators across constructs measuring different phenomena, relative to the average of the the the correlations of indicators within the same construct (Henseler et al, 2015). HTMT test approach indicates that HTMT values must be significantly less than 1, with a value of less than 0.85 ideal (Henseler et al, 2015). Table 1.6 indicates that the highest HTMT value is 0.604, confirming the model possesses adequate discriminant validity.

Table 1.6: Heterotrait-Monotrait Ratio (HTMT)

	BCDA	BCDDC	BCMGT	BCOL	BCPS	BCRES	BCTCH	ERP	FP
BCDA									
BCDDC	0.728								
BCMGT	0.764	0.518							
BCOL	0.546	0.695	0.473						
BCPS	0.795	0.735	0.806	0.665					
BCRES	0.792	0.6	0.828	0.405	0.79				
BCTCH	0.855	0.706	0.86	0.494	0.775	0.932			
ERP	0.68	0.624	0.556	0.309	0.558	0.555	0.632		
FP	0.826	0.638	0.657	0.596	0.722	0.658	0.784	0.593	

5. Structural Model Results

The study's findings were analyzed for the structural model after evaluating the validity and reliability of the model. As a standardized trajectory coefficient PLS provides the scope and significance of hypothesized causal relationship (Hair et al., 2019). In the hypothesized direction of the effect, the parameter estimate of the assumed structural path should be statistically important. If the p value is below the meaning level of 0.05, a direction is considered statistically important. The researchers conducted the bootstrapping study to determine the statistical significance of the loads of the route coefficient (Hair et al., 2014). A Bootstrapping is a technique to resample a large number of subsamples (with replacement) from the original data and to approximate models for each subsample. The researchers thus get a large number of model

estimates (typically 5000 or more), which can be used to measure a standard mistake of each parameter of the model. The importance of each parameter can be calculated by means of t-values, based on the standard error (Hair et al., 2014). The path coefficients represent the power of the connections between the buildings, while the t-values calculate the sense of the path coefficient.

Figure 1.2 indicates the path coefficients of the study model, and Figure 4.2 displays t-values. The structural model results are summarized in Table 1.7.
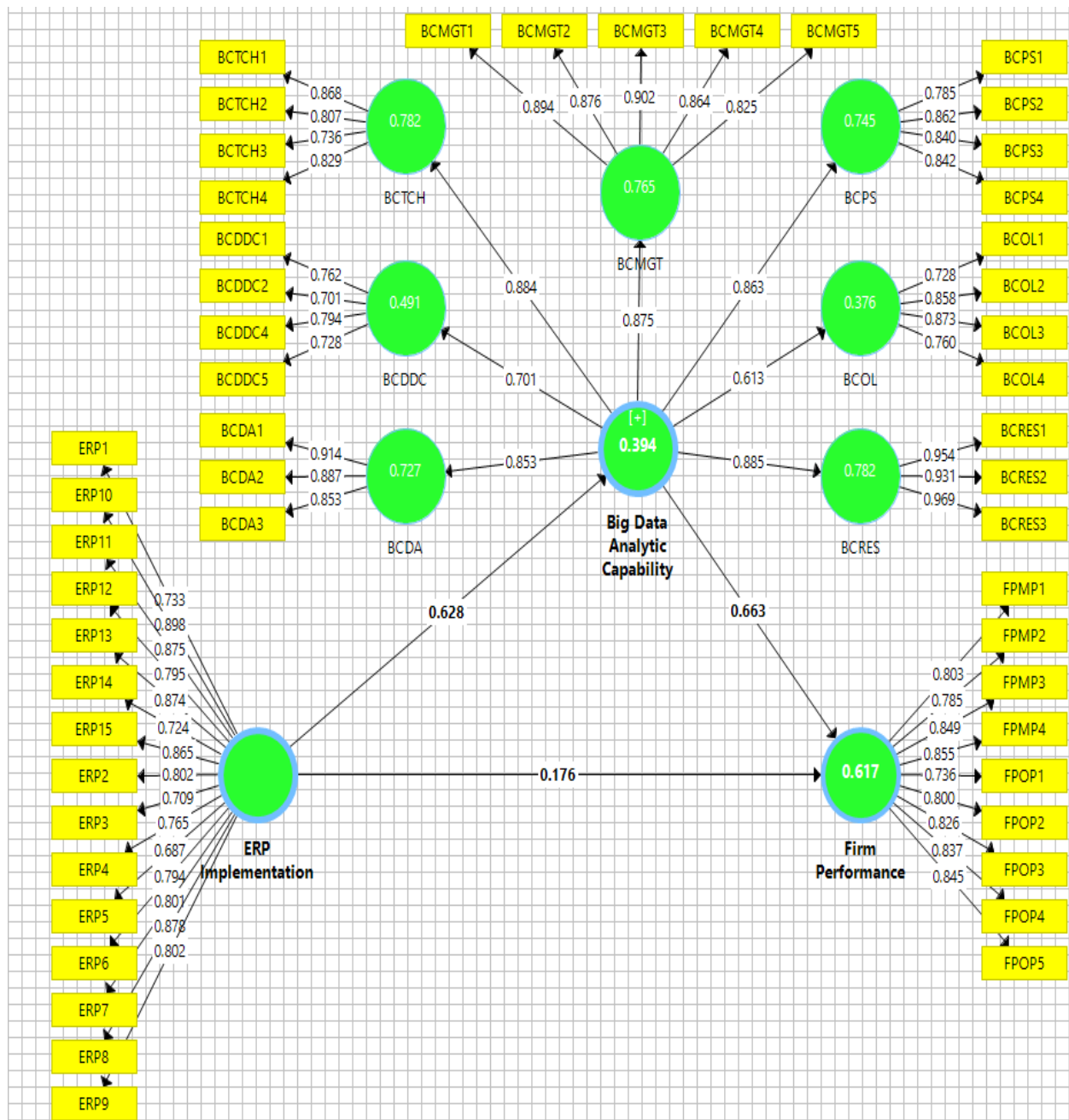
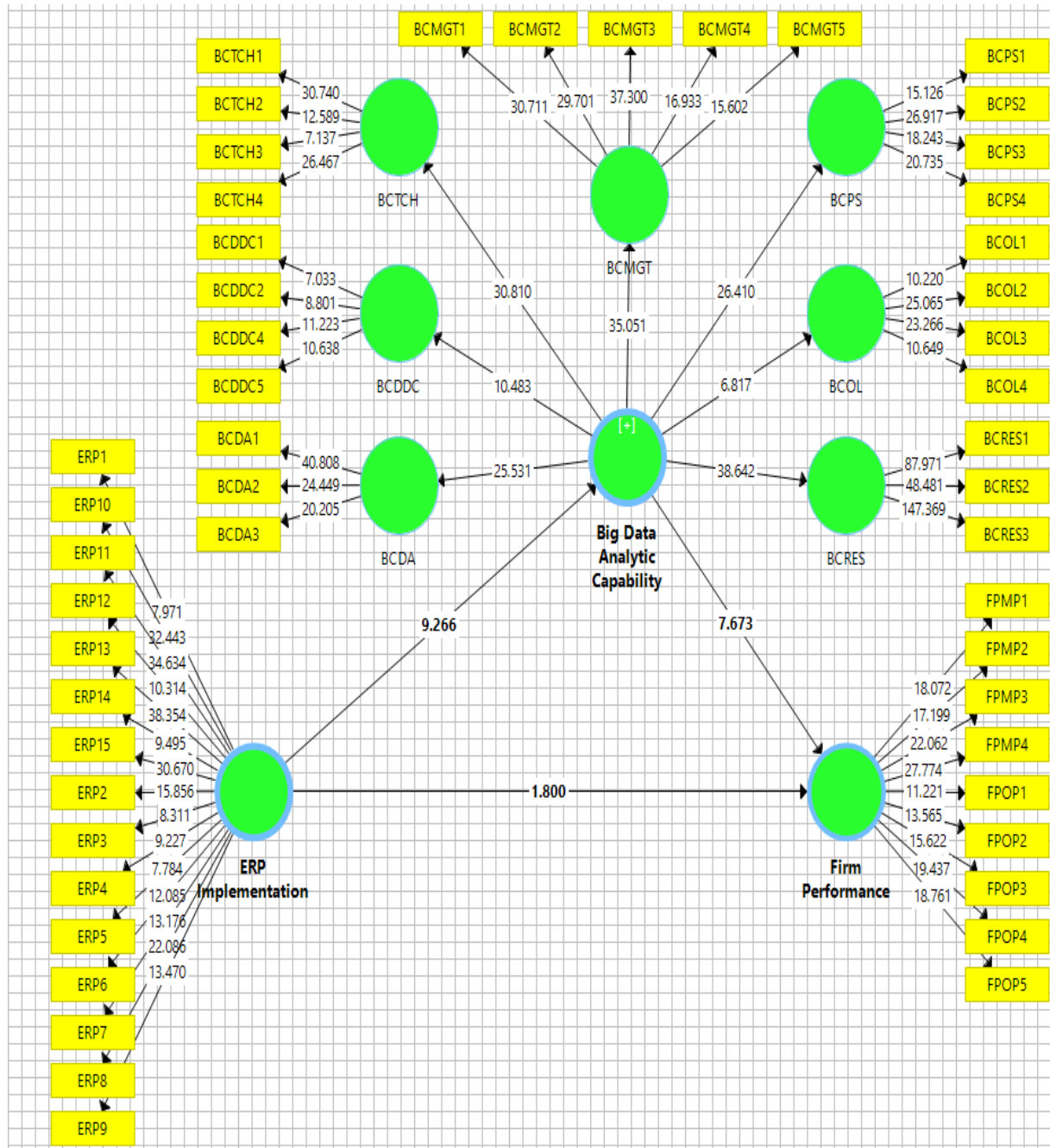**Figure 1.3:** Research Model Showing Path Co-Efficient Results

Figure 5.2: Research Model Showing T-values

Hypothesis Testing
The bootstrapping results were used to analyze various hypotheses proposed in by this study. The acceptable standards required for hypothesis testing is through the use of t-values greater than or equal to 1.96 in addition to p-values less than 0.05.

5.1 Hypotheses Testing

Hypotheses		Original Sample (O)	T Statistics (|O/STDEV|)	P Values	Decision
H1	ERP -> BDAC	0.628	9.266	0	Supported
H2	ERP -> FP	0.176	1.8	0.072	Not Supported
H3	BDAC -> FP	0.663	7.673	0	
Mediation Test					
H4	ERP -> BDAC -> FP	0.416	5.38	0	Supported

The hypothesis H1 illustrate the direct effect of ERP on big data analytics capability. The results show that ERP has a positive and significant effect on bid data analytics capability with $\beta = 0.628$, t-value = 9.266, p-value = 0.
The hypothesis H2 depicts the impact of ERP on firm performance. The results indicate that ERP has a positive but insignificant effect on firm performance ($\beta = 0.176$, t-value = 1.8, p-value = 0.72). Thus, the hypothesis was not supported.
Again, the results show that hypothesis 3 which indicates that the effect big data analytics capability on firm performance is supported with a $\beta = 0.628$, t-value = 9.266, p-value = 0.
The last hypothesis H4 depicts the mediating role of big data analytics capability on the path from ERP to firm performance. The results show that big data analytics capability positively mediates the relationship between ERP and firm performance with a $\beta = 0.416$, t-value = 5.368, p-value = 0. Since the direct effect of ERP to firm performance was not significant, the implication is that big data analytics capability fully mediates the relationship between ERP implementation the firm performance.

6. Discussion of Results

The main objective of this study was to explore the connection between the ERP implementation, the capacity for big data analytics and corporate performance. The study first explores the influence of the ERP execution on the capability of big data analytics. The study finds that the introduction of ERP has a clear and positive effect on the organizational potential of big data analysis. This result supports studies that say that ERP offers broad data analytics capabilities to companies (Shi and Wang, 2018; Sun et al., 2018). Second, the analysis explores the direct impact on company results of implementation of the ERP and Big Data Analytics. The results of the study indicate a favorable but marginal effect on company efficiency on implementation of ERP. Although the research supports existing studies that have shown a positive impact on firm performance of implementation by ERP (Le and Han, 2016, Tarigan et al., 2020), the findings of ERP implementation on corporate performance are somewhat contradicted by the fact that they have a statistically minor effect on corporate performance. On the contrary, the results indicate the

strong positive and substantial impact on the organizational efficiency of the broad data analytics capability. This finding confirms the Wamba et al. (2019) report, in which the capacity of organizational big data to achieve enhanced organizational efficiency has been demonstrated. The study also explores the role of mediation in the capacity for big data analytics on the road from ERP towards business efficiency. The results show that the capacity for big data analytics positively affects ERP's relationship with company success. Again, because the direct impact of ERP on the company results was negligible, the result is that the capacity for Big Data Analytics completely mediates the link between ERP's performance. This result provides a justification for studies which have opined for the need for studies to examine the mechanisms through which ERP influences firm performance (Elgohary, 2019; Hassab Elnaby et al., 2012).

The various outcomes of this analysis is examined and the results of the analysis are underlined. It also sets out guidelines, findings, limitations and potential areas for further research.

7. Practical Implication

The study offers some practical implications. In all the study affirms the relevance ERP implementation and big data analytics capability in improving firm performance.

First, the findings of the study disclosed that ERP implementation has a positive and significant influence on organization big data capabilities. This result suggests that when organizations implement ERP, it presents them with several capabilities which includes the ability to handle and process big data to derive useful information for the effective and efficient operations. When adopting ERP, firms must undertake activities such as training employees with requisite and the requisite skills of use ERP, and effective change management to facilitate the and effective and efficient use of the system to reap its benefits (Altamony et al., 2016)

Again, the study finds that big data analytic capability has a positive and significant effect on organizational performance. This result indicates that an organization with high levels of big data analytic capability are more likely to attain high levels of innovativeness. The implication of this result is that organizations seeking to improve upon their performance must endeavor to build capabilities in the area of big data. The implementation of ERP will not only provide big data analytics capabilities but also enhances firm performance.

While the study provides several useful findings, there are some limitations. First, the study was undertaken in Ghana whose prevailing environmental conditions are distinct from other countries. Therefore, the results of this study may not fully apply to firms in countries whose environmental contexts are different from that of Ghana. Therefore, this the study recommends that future works may replicate the conceptual framework in other countries to validate its applicability in different environmental contexts. Again, the study used data obtained from 74 respondents. While this data was adequate to undertake this study (Hair et al., 2019), a higher number of data set would have improved the representativeness of the sample size (Brtnikova et al., 2018). Again, the study recommends that future studies should extend the model with some contextual variables and examine the underlying conditions through which ERP influence form performance.

7.1 Conclusion

This study attempts to study mechanisms that affect the performance of organizations through implementation of ERPs and the Big Data Analytics capability. The study used resource-based view theory as its theoretical underpinning for the development of a research model. The research model conceptualized that the implementation of the ERP has a direct positive impact on the organizational capacity of large data and also on firm performance. The research model for this

study was empirically validated with empirical data from 74 respondents. The PLS-SEM analytical technique was used to analyze the research model. The study also found support for three of the four hypotheses formulated further findings of the study revealed that the capabilities of large data analytics mediate the relationship between ERP implementation and performance.

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