



**QUALITY OF SERVICE-BASED SELECTION MODEL FOR SOFTWARE  
AS-A-SERVICE IN SMALL AND MEDIUM ENTERPRISES**

**OGUNRINDE ROWLAND ROTIMI**

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**QUALITY OF SERVICE-BASED SELECTION MODEL FOR SOFTWARE-  
AS-A-SERVICE IN SMALL AND MEDIUM ENTERPRISES**

By

**OGUNRINDE ROWLAND ROTIMI**

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia,  
in fulfillment of the Requirements for the Degree of Doctor of Philosophy**

**May 2019**

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## DEDICATION

*I dedicate this thesis to my one and only beloved wife –*

*Assoc. Prof. Dr. Roseline B., Ogunrinde*



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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Doctor of Philosophy

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**OGUNRINDE ROWLAND ROTIMI**

May 2019

**Chairman : Associate Professor Yusmadi Yah Binti Jusoh, PhD**  
**Faculty : Computer Science and Information Technology**

Enterprise applications (EAs) are known to assist organizations achieve operational excellence and competitive advantage. Small and Medium Enterprises (SMEs) which are the major drivers of most thriving global economies use the on-premise EAs which are known to be costly. This creates business challenge of competitively thriving in the same market environment with their large enterprise counterparts. The advent of Cloud computing (CC) offers the SMEs opportunity of accessing cheap cloud-hosted EA services delivered as Software-as-a-Service (SaaS) on pay-per-use basis bypassing huge initial capital. However, existence of numerous Cloud Service Providers (CSPs) offering Cloud EAs leaves a challenge of selecting a suitable and cost-efficient provider of application that is based on meeting the SMEs' customized Quality of Service (QoS) requirements. More so, the excessively large number of QoS attributes on which the CSPs are assessed can be derailing to the selection suitability quest of the SMEs. Therefore, the objectives of this study are to explore the selection criteria, analyze the attributes that are relevant and important to the SMEs to avoid overlapping functionalities, and to propose a QoS based model for SaaS selection in the SME. Seven selection criteria and 179 QoS attributes were identified from the literature while 29 QoS attributes emerged after analysis using sharing and combination process, and this forms the basis of the research hypotheses. Consequently, a confirmation study was conducted which includes a review by panel of experts, a pilot study and an empirical study. The result of the empirical study indicates the degree of importance of the selection criteria and attributes forming the basis of derivation of the selection criteria's Global Weight of Factor (GWF) utilized in the SaaS selection process. The hypothetical relationships were tested using Partial Least Squares - Structural Equation Modeling (PLS-SEM). The proposed model known as Quality of Service based Selection Model (QSSM) for SaaS consists of service request, service selection criteria with their attributes, and the Cloud enterprise selection process where weighting, ranking and cost-based comparison takes place to make the final ranking based on service suitability and cost. A prototype named as QSS System is developed and

validated by expert review panel and users to indicate its feasibility and acceptability. Results show that QSS system is beneficial in selecting suitable and cost-efficient CSP. Research findings indicate that the QSSM achieved an acceptable fit with six of the seven main hypotheses. The proposed model provides a comprehensive analysis of important selection criteria while making investment decisions from the SMEs' perspectives. This study also contributes to the practical insights into achieving service selection suitability with a model that tends to minimize the gap between the SMEs' QoS requirements and the characteristics of the system by considering the QoS importance rating for selection. Incorporation of cost-efficiency selection component in the model is a step further that will help cut cost for the SMEs adopting the Cloud.



Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

**KUALITI SERVIS BERDASARKAN PEMILIHAN MODEL UNTUK  
PERISIAN-SEBAGAI-PERKHIDMATAN DALAM PERUSAHAAN KECIL  
DAN SEDERHANA**

Oleh

**OGUNRINDE ROWLAND ROTIMI**

Mei 2019

**Pengerusi : Profesor Madya Yusmadi Yah Binti Jusoh, PhD**  
**Fakulti : Sains Komputer dan Teknologi Maklumat**

Aplikasi perusahaan (EAs) dikenali untuk membantu organisasi mencapai kecemerlangan dalam operasi dan kelebihan dalam persaingan kompetitif. Perusahaan Kecil dan Sederhana (SMEs) yang mana adalah pemangkin utama untuk ekonomi dunia berkembang maju menggunakan platform (EA's) yang mana diketahui berkos tinggi. Ini menjadikan cabaran perniagaan berkembang maju dalam pasaran yang sama dengan rakan perusahaan yang lebih besar. Kemunculan Pengkomputeran Awan (CC) menawarkan peluang untuk SMEs dalam mengakses perkhidmatan Awan dihoskan EA yang berkos rendah untuk dihantar sebagai Perisian sebagai perkhidmatan (SaaS) dalam asas bayar-per-guna memintas modal pemulaan yang besar. Bagaimanapun, kewujudan pelbagai Pembekal Perkhidmatan Awan (CSPs) menawarkan Awan EAs meninggalkan satu cabaran dalam pemilihan pembekal aplikasi yang sesuai dan kos cekap yang bergantung pada memenuhi keperluan Servis yang Berkualiti (QoS) SMEs. Selain itu, nilai jumlah yang lebih besar dari QoS memberi kesan di mana CSP's yang dinilai mungkin boleh menjejaskan pemilihan SME's yang sesuai. Oleh itu, objektif kajian ini adalah untuk meneroka pemilihan kriteria, analisis attribute yang berkaitan dan penting kepada SMEs untuk mengelakkan pertindihan fungsi-fungsi, dan untuk cadangkan satu model QoS untuk pemilihan SaaS dalam SME. Tujuh pemilihan kriteria dan 179 atribut QoS dikenalpasti dari kajian kesusasteraan sementara 29 atribut QoS muncul selepas analisis yang menggunakan proses perkongsian dan kombinasi, dan ianya membentuk asas kepada hipotesis penyelidikan. Maka, kajian pengesahan telah dijalankan di mana meliputi kajian semula oleh panel pakar, kajian perintis, dan kajian empirikal. Hasil daripada keputusan kajian empirikal menunjukkan tahap kepentingan pemilihan kriteria dan atribut yang membentuk asas derivasi daripada pemilihan kriteria *Global Weight of Factor* (GWF) yang digunakan dalam proses pemilihan (SaaS). Hubungan hipotesis diuji menggunakan *Partial Least Squares-Structural Equation Modeling* (PLS-SEM). Model yang dicadangkan dikenali sebagai Servis yang Berkualiti

berdasarkan Model Pemilihan (QSSM) untuk SaaS terdiri daripada perkhidmatan permintaan, perkhidmatan pemilihan kriteria dengan atribut, dan proses pemilihan Perusahaan Awan di mana pemberat, kedudukan dan perbandingan kos diambil kira untuk membuat keputusan terakhir berdasarkan perkhidmatan yang bersesuaian dan kos. Satu prototaip yang bernama QSS sistem telah direka dan disahkan oleh pakar kajian semula dan pengguna untuk menunjukkan kelayakan dan kebolehterimaan. Keputusan QSS sistem berguna dalam pemilihan yang sesuai dan kos-cekap CSP. Hasil penyelidikan menunjukkan QSSM mencapai piawai dengan enam daripada tujuh hipotesis utama. Model yang dicadangkan menyediakan analisis yang komprehensif mengenai kepentingan pemilihan kriteria sementara membuat keputusan pelaburan dari perspektif SMEs. Pengajian ini menyumbangkan kepada wawasan praktikal dalam mencapai perkhidmatan pemilihan yang sesuai dengan model yang meminimumkan jurang di antara keperluan SMEs QoS dan ciri-ciri sistem dengan mempertimbangkan kepentingan penilaian pemilihan QoS. Pemilihan komponen kos-cekap dalam model adalah satu langkah ke hadapan yang boleh membantu mengurangkan kos untuk SMEs menggunakan Awan.



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Signature: \_\_\_\_\_  
Name of Chairman  
of Supervisory  
Committee: Associate Professor Dr. Yusmadi Yah Binti Jusoh

Signature: \_\_\_\_\_  
Name of Member  
of Supervisory  
Committee: Associate Professor Dr. Noraini Che Pa

Signature: \_\_\_\_\_  
Name of Member  
of Supervisory  
Committee: Associate Professor Dr. Wan Nurhayati Wan Ab. Rahman

Signature: \_\_\_\_\_  
Name of Member  
of Supervisory  
Committee: Associate Professor Dr. Azizol Abdullah

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## LIST OF ABBREVIATIONS

ABS	Accounting and Billing Systems
ACC	Accountability
ACM	Association for Computing Machinery
AHP	Analytic Hierarchy Process
AGT	Agility
AJAX	Asynchronous JavaScript and XML
ANP	Analytic Network Process
ASS	Assurance
AVE	Average Variance Extracted
BI	Business Intelligence
CA	Cronbach Alpha
CAPEX	Capital Expenditure
CC	Cloud Computing
CEA	Cloud Enterprise Applications
CEAS	Cloud Enterprise Applications Selection
CGW	Converted Global Weight
CR	Composite Reliability
CRM	Customer Relationship Management
CSS	Cascading Style Sheets
CSMIC	Cloud Services Measurement Initiative Consortium
CST	Cost
CSP	Cloud Service Provider
EAs	Enterprise Applications
EAM	Enterprise Asset Management

ECM	Enterprise Content Management
ERP	Enterprise Resource Planning
FK	Foreign Key
GEEs	Generalized Estimating Equations
GUI	Graphical User Interface
GWF	Global Weight of Factor
H	Hypothesis
HRM	Human Resource Management
HTML	Hyper Text Markup Language
HTTP	Hypertext Transfer Protocol
IaaS	Infrastructure as a Service
IEEE	Institute of Electrical and Electronics Engineers
IPMA	Importance-Performance Map Analysis
IS	Information Systems
IT	Information Technology
ICT	Information and Communication Technology
KPI	Key Performance Index
LWA	Local Weight of Attribute
MCDA	Multi-Criteria Decision Analysis
MIS	Management of Information Systems
NDA	Non-Disclosure Agreement
OPEX	Operational Expenditure
PaaS	Platform as a Service
PFM	Performance
PHP	Hypertext Preprocessor
PK	Primary Key



PLS	Partial Least Squares
PLS-SEM	Partial Least Square – Structural Equation Modeling
PROMETHEE	Preference Ranking Organization Method for Enrichment of Evaluation
QoS	Quality of Service
QSSM	Quality of Service based Selection Model
SaaS	Software as a Service
R	Reviewer
RQ	Research Question
RSS	Raw Score of Service
SCM	Supply Chain Management
SD	Standard Deviation
SDM	System Development Methodology
SEM	Structural Equation Modeling
SLA	Service Level Agreement
SMEs	Small and Medium Enterprises
SMI	Service Measurement Index
S&P	Security and Privacy
SUS	System Usability Scale
UML	Universal Modeling Language
USB	Usability
WSM	Weighted Scoring Matrix
WSS	Weighted Score of Service
XAMPP	Cross-Platform (X), Apache (A), MySQL (M), PHP (P) and Perl (P)
cf.	“confer” (latin) meaning compare (one source with another)
et al.	“et alii” (latin) meaning “and other authors”

cont'd	continued
id	identity
i.e.	“id est” (latin) meaning “that is”
int	integer
p., pp.	Page(s)
%	Percentage
varchar	variable-length character



# CHAPTER 1

## INTRODUCTION

### 1.1 Background

Cloud Computing (CC) is one paradigm shift in contemporary technology which has gained a tremendous attention in the research community in recent times. This technology employs a remote network of servers to store, process, and manage data over the Internet. Many organizations, including the Small and Medium Enterprises (SMEs), have seized its numerous advantages to reduce the costs associated with the management of hardware and software resources. This reduction in initial capital expenditure and provision of availability of real time services on pay-per-use basis has been an enticing reason for many organizations to adopt this technology, most especially the SMEs (Mahmood and Saeed, 2013). A major problem, though, lies in the selection of this new technology to meet organization's personalized needs and cut cost. Our main focus in this research work is to address selection challenges associated with suitability of choice during the process of choosing software as a service (SaaS) for the organization by presenting relevant quality of service (QoS) attributes while also attempting to consider the cost efficiency of the choice. This chapter is made up of some sessions and sub-sessions starting with the motivation behind the study, statement of research problems to be addressed, research objectives intended to be achieved, the scope of the research, and of course, the contribution of this study to the body of knowledge.

### 1.2 Research Motivation

The existence of traditional enterprise applications (EA's) has covered close to three decades, under the condition of which organizational data reside within the premise of the organizations owing them (Scavo *et al*, 2012). Enterprise applications automate and integrate business management activities (including both internal and external management of information) across an entire organization with an integrated software application thereby helping the organization achieve operational excellence and competitive advantage.

EA's are crucial to the business operations in the SMEs to improve productivity, efficiency and overall business performance (Vandit *et al*, 2013). However, running the traditional EA's have been observed to be too costly for most Small and Medium Enterprises (SMEs) (Haddara, 2011) which are known to be "the major driving force of any thriving and agile economy globally" (Monika *et al*, 2010; Azarnik *et al*, 2012).

However, many enterprises have leveraged on the several opportunities (such as scalability, flexibility, cost effectiveness, reliability, broad network access, etc.,) presented by the emergence of Cloud computing to "jump" from the traditional

business approaches to the Cloud-based business models. Cloud computing has been described as a paradigm technology of accessing a network of remote servers via the Internet for the purpose of managing, processing and storing data, instead of using the local servers or one's personal computers (Lin and Chen, 2012; Totiya and Senivongse, 2017). Consequently, Cloud-based EA's which are basically provided using the Software-as-a-Service (SaaS) architecture, now offers the SMEs with opportunity of a situation where users rent the software and use, rather than buy it (Ivanov 2012). Hence, it is seen as a viable answer to the high cost challenge for SMEs (Monika *et al*, 2010; Islam *et al*, 2013; Abdulkader and Abualkishik, 2013). Consequently, one can say that Cloud enterprise application (CEA) is a resultant name from combining enterprise applications and Cloud Computing, or simply put, enterprise applications hosted in the Cloud; whereby they are offered as software-as-a-service.

Cloud computing services market has grown stupendously over the last decade. After Cloud computing was made popular by Amazon's Elastic Compute Cloud in 2006 (Sotomayor *et al.*, 2009), the size of the global public Cloud market was projected to reach 97 billion US dollars in 2015 and further grow to 159 billion US dollars in 2020, with the software-as-a-service (SaaS) delivery model being the biggest driver (Columbus, 2015). This also underscores the basis of why this study is focused on SaaS.

In spite of the incredible projected Cloud growth and the numerous benefits of Cloud computing, many organizations, most especially, the Small and Medium Enterprises, are hesitant and afraid to adopt the cloud on the ground of possible failure (Islam *et al*, 2013; Kilic *et al*, 2015). Selection of suitably fitting solutions remains a challenge and stumbling block to a widespread adoption of this paradigm technology still by many organizations. However, research, as well as observation in the industry, has proved that adoption of cloud computing was found to be higher in Small and Medium Enterprises (SME's) than in Large organizations (Islam *et al*, 2013). This is found to be so apparently due to two major reasons namely, the reduced and affordable capital expenditure to access a pool of incredible computing resources at pay-per-use (Reza *et al*, 2013) and the fact that they have not as much assets to lose as the large enterprises in case of any possible eventual breach of data migrated to the cloud (Monika *et al*, 2010; Islam *et al*, 2013). Also, the financial capability of the Large Enterprises (LEs) to implement the conventional traditional technologies has been found to be another reason Cloud adoption rate is greater in the SMEs than in the large enterprises (Islam *et al*, 2013). This study is motivated to be carried out in the SME domain as a result of this observed higher adoption rate by the SME than the large enterprises.

Generally, based on the fact that the value proposition of Cloud computing which has remained crystal clear from the beginning – with all its essential characteristics – adoption rates are running faster than ever before. In a research report released in the European Union in 2014, though both large enterprises and the SMEs express concern about risk of a security breach with the highest scores among several limiting factors

of adopting the Cloud with 57% and 38% respectively, large enterprises and the SMEs express a considerable disparity regarding other factors. Statistics show that a whopping 32% regard high cost as one of the prominent limiting factors as compared to 17% in the large enterprises (Giannakouris and Smihily, 2017). The implication of this statistics is that while large enterprises are more concerned with security than cost issues in the Cloud, the SMEs indicate cost as a more important factor to consider than security in the Cloud.

Yet, in the midst of the hype, there are no one-size-fit-all solutions among Cloud services, while also, Cloud service providers offer varying quality of service (QoS) at different costs as requirements differ from one organization to another (Johansson *et al*, 2015). The need to close the wide gap that exists between users QoS preferences and the selected system in most service selection scenarios has been identified by previous researchers (Subha and Saravanan, 2013; Mallayya *et al*, 2015; Upadhyay, 2017). Consequently, selecting the most suitable service providers for the SMEs, and at the most affordable rate, remains key to the survival of the SMEs in the Cloud as several reports of project failure have been seen due to wrong decision making in the process of selecting a service.

Since selecting a suitable Cloud Service Provider in Cloud Computing is a broad topic, this research will focus on selection by weighting and ranking of criteria as this is expected to provide a more detailed analysis and deeper level of understanding of this domain.

### **1.3 Problem Statement**

Small and medium enterprises (SMEs) have restricted resources, minimal budgets, and limited access to financial aid and therefore are greatly sensitive to costs. The Cloud Computing provides the SMEs with amazing computing infrastructure at affordable costs compared to the traditional enterprise applications which is rather on the high side, usually due to huge initial capital involved in acquiring infrastructure and maintaining them. Selecting the most suitable software-as-a-service has been known to be a complex and challenging decision in any sector. Historically, over 50% of the I.T projects failed within the first year without realizing their projected financial profit (Florentine, 2016; Egbokhare, 2014) as financial consequences of business investments, decisions, or actions (Kornevs *et al*, 2012). Prominent among the factors accounting for this failure has been identified as lack of suitability between the personalized needs of the organization and the behavior of the system (H.S. Kilic *et al*, 2015). These needs are expressed in the QoS requirements by the organizations. The overwhelming array of QoS attributes to be assessed at times causes derailment to the quest for suitable service selection (Repschläger, 2012). Bridging the gap between users QoS preferences and the functionality of the selected service has been identified as a formidable challenge to suitable service selection (Subha and Saravanan, 2013; Mallayya *et al*, 2015; Upadhyay, 2017).

Moreover, several services which are either same or similar in quality are provided by different Cloud providers at varying costs, even though it is believed that “the more costly a service is, the better the quality” (Chang *et al*, 2012). Much research have been done on selecting best service providers considering several criteria, however, how to get the most cost efficient among the several suitable services has not gained sufficient exploration (Weintraub and Cohen, 2015). In the midst of the stiff competition among various Cloud service providers for better services with low pricing, customers have been observed to base their choices on their QoS and pricing (Baranwal and Vidyarthi, 2016). Consequently, it becomes necessary for the SMEs who desire to further cut the cost of adopting the best Cloud service to be able to select an optimal cloud service provider with the most affordable offer amongst a set of providers that best meet the personalized QoS requirements of the organization. Hence, priority assessment of a set of quality attributes in the SME context are needed in order to guide users focus on the higher priority ones while ensuring that the bare minimum expectation of the remaining ones are attainable (Chun *et al*, 2014).

#### **1.4 Research Questions**

The questions this research intends to answer are as highlighted below:

- What are the relevant QoS attributes considered by the SMEs while selecting software-as-a-service?
- How much importance do the SMEs attach to the varying QoS attributes while considering software-as-a-service for selection?
- Since “a more costly service is usually more reliable” (Chang *et al*, 2012), how can the SMEs select a suitable service provider that offers the most affordable services among a catalogue of best providers with similar level of QoS?

#### **1.5 Research Objectives**

In order to attempt to solve the under-mentioned problem statement of this research, this study has outlined the following research objectives:-

- To analyze the criteria and QoS attributes for selecting suitable software-as-a-service for the SMEs.
- To propose a QoS based Selection Model (QSSM) for selecting a cost effective option among a set of Cloud providers that best meet the essential QoS requirements of the SME and validate the model through development of a prototype.



The two research objectives were formulated with the expectation that, providing answers to them would yield information that will sufficiently guide the SMEs in their search for Cloud providers that can meet users' needs to an appreciable extent. Besides that, the research objectives enable the users to obtain most suitable provider.

## **1.6 Research Scope**

Conducting a research on the subject of Cloud service selection as a whole will not only mean researching into a wide range of issues that might adversely affect achieving the objectives of this study, but would also amount to stretching the projected or available resources meant to accomplish the study, such as fund, time, space and so on. As a result, this section is aimed at limiting scope and context of this research in order to make it manageable.

This study encompasses both private and public organizations in Malaysia. The reason for inclusion of both sectors is that adoption of SaaS is more widespread in private organizations than in public sector in most places globally (Craig *et al*, 2009; Kurzac, 2017).

This research was conducted on the basis of developing a model to guide the SMEs in selecting suitable Cloud service providers. The foundations of the criteria and QoS attributes proposed for the conceptual framework are based on the study of literature, analysis on the existing selection frameworks and models as well as expert reviews.

Since early 2000's, many have 'prophesized' the rising of Software as a Service as the most lucrative and used software delivery model (Turner, 2003). Even till date, SaaS delivery model is still projected as being the biggest driver of the future Cloud market by year 2020 (Columbus, 2015), The overwhelming adoption rate of the SaaS above other delivery models makes this phenomenon worth investigating. Therefore, enterprise applications will be viewed in the representation of the SaaS delivery in this study.

This study incorporates only the small and medium size organizations.

This study is based on empirical research and focuses on respondents with experience using the Cloud services. The proposed model is then validated by a prototype to evaluate the suitability of the service to the SMEs' QoS requirements.

## **1.7 Research Contribution**

This study is expected to serve as a guide in decision making for prospective software-as-a-service client. The model is targeted at SME Cloud service consumers to make an informed choice in selecting suitable service provider at the most affordable cost

among many providers offering same level of Quality of Service, i.e., getting maximum cloud benefits at the lowest available cost.

Adoption of the SMI model in selection of Cloud services is another area of contribution to the body of knowledge as the study is expected to give another insight into the application of this model as a larger proportion of previous research have focused on its use in Cloud adoption rather than in Cloud selection.

The proposed QoS based selection model (QSSM) will reduce the possibility of Cloud hosted software adoption/implementation failure due to its attempt to reduce the gap between the needs (QoS preference) of the organization and the characteristics of the system thereby improving suitability of selected service.

Inclusion of cost comparator which is a cost efficiency apparatus to the system apart from the initial cost criterion evaluation is another plus to this study in that it will afford the SMEs the opportunity of procuring the most affordable of the best suited Cloud services.

This study can be a source of baseline information on recent status of Cloud enterprise application service selection for SMEs for future research.

## **1.8 Organization of Thesis**

This thesis is organized into eight (8) chapters. Each chapter is briefly summarily presented below:

**Chapter 1** introduces the overall study of this thesis. Motivation for the research, problem background and statement, research objectives, scope as well as the contributions of the research are explained in this chapter.

**Chapter 2** presents a detailed and in-depth study of several subjects or sub-topics which needed to be critically analyzed to be able to understand the trend, gaps as well as the current issues in our areas of concern. The literature review covers Cloud computing, the SMEs, the software-as-a-service, quality of service, and most importantly, a critical analysis of previous works on selection of service providers in the Cloud environment.

**Chapter 3** describes the methodology adopted for the research. It describes the tools, materials and methods used to carry out the tool design, data collection, analysis, and identification of metrics and evaluation strategy.



**Chapter 4** discusses the development of the hypotheses which the study tested. The chapter includes the measurement model.

**Chapter 5** provides a detailed description of the proposed model. The chapter describes the structure of the model, including its components, sub-components and their functionalities to a detailed extent.

**Chapter 6** provides a comprehensive description of the prototype designing in implementation of the QoS based selection (QSS) solution. The phases involved in the development process comprising the initial analysis, functional specifications, construction and implementation, as well as the development tools employed in the development are discussed in detail. It concludes with the evaluation involved in the testing of the prototype using the expert validation and system usability scale.

**Chapter 7** presents an in-depth discussion on the findings of this research. This includes discussion on the significance of the relationships between proposed variables. A detailed discussion on the evaluation of the proposed model and the prototype to ascertain its validity is also presented.

**Chapter 8** basically presents the summary of the general discussion of the research findings, conclusion, research contribution and future work of the research documented in this thesis, proposing some research directions which can be further investigated as future works.

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