AN INTEGRATED SOFTWARE QUALITY MODEL IN A FUZZY ANALYTICAL HIERARCHY PROCESS-BASED EVALUATION FRAMEWORK FOR E-LEARNING SOFTWARE

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ABSTRACT

The demand in implementing e-Learning in organisations has triggered the emergence of numerous e-Learning software (e-LS). Thus, it is necessary for organisations to select the correct e-LS for use within their organisations. The evaluation and selection of the e-LS can be complex and difficult because it involves many processes which are related to the evaluation criteria and the evaluation technique. For this purpose, the Software Quality Model (SQM) such as the ISO/IEC 9126-1 Quality Model can be used as a reference as it offers a list of criteria which encompass *Functionality, Usability, Maintainability, Efficiency, Portability* and *Reliability.* These are commonly used as criteria for evaluating the e-Learning software. In addition to this, the Commercial-Off-The Shelf (COTS) framework is also useful although it provides a different set of criteria such as *Cost, Vendor, Product Benefits, Risk and Uncertainty* and *Organizational.* It commonly uses the Multi Criteria Decision Making (MCDM) technique which includes the Analytical Hierarchy Process (AHP) for any software evaluation. The limitation of the AHP is its inability to handle any uncertain criteria in the evaluation process implying that there is no adequate evaluation framework that can currently be applied to evaluate the e-LS more appropriately. This is because the important criteria and sub-criteria that can be used to evaluate the e-LS have not been adequately identified. This study attempts to formulate an evaluation framework that can be adequately used for the e-LS evaluation. The framework incorporates the e-LS quality model which comprises the important criteria for evaluating the e-LS. The framework developed in this study is supported by a tool that is based on the Fuzzy AHP technique which addresses the limitation of the AHP. More than 250 related articles and references were reviewed for the purpose of identifying the key criteria for the e-LS evaluation. The Delphi survey was conducted to obtain a list of additional criteria based on the consensus of 31 local e-Learning experts. A total of 11 criteria and

66 sub-criteria were extracted from literature review while 16 additional sub-criteria were provided by the experts. In total, 11 criteria and 81 sub-criteria were validated by the experts' consensus. Based on this, an Integrated Software Quality Model (ISQM) was then constructed. An e-LS evaluation framework consolidating the ISQM with the Fuzzy AHP technique, namely the ISQM-Fuzzy AHP, was then formulated. The tool, called the e-LSO, was then developed to assist in the e-LS evaluation. A usability evaluation of the e-LSO was tested via the Post-Study System Usability Questionnaire (PSSUQ) involving five e-LS experts. The results revealed that the experts were satisfied with the e-LSO and they also approved of it as a useful tool for the e-LS evaluation. Overall, it can be said that the ISQM-Fuzzy AHP can serve as a guideline and support for organisations in their e-LS evaluation processes. The e-LSO can also assist organisations to create their own decision models for the e-LS evaluation easily.

ABSTRAK

Permintaan dalam melaksanakan e-Pembelajaran dalam organisasi telah mencetuskan kemunculan banyak *Perisian e-Pembelajaran (Pe-P).* Oleh itu, organisasi perlu memilih *Pe-P* yang betul untuk digunakan dalam organisasi mereka. Penilaian dan pemilihan *Pe-P* boleh menjadi rumit dan sukar kerana ia melibatkan banyak proses yang berkaitan dengan kriteria penilaian dan teknik penilaian. Untuk tujuan ini, *Model Kualiti Perisian (MKP)* seperti Model Kualiti ISO/IEC 9126-1 boleh digunakan sebagai rujukan kerana ia menawarkan senarai kriteria yang merangkumi *Kebolehfungsian, Kebolehgunaan, Kebolehselenggaraan, Kecekapan, Kemudahalihan* dan *Kebolehpercayaan*. Ini biasanya digunakan sebagai kriteria untuk menilai *Pe-P*. Di samping itu, rangka kerja Commersial-Off-The Shelf (COTS) juga berguna walaupun ia menyediakan suatu set kriteria yang berbeza seperti *Kos, Penjual, Manfaat Produk, Risiko dan Ketidakpastian* dan *Organisasi*. Ia biasanya menggunakan teknik *Membuat Keputusan Pelbagai Kriteria (MKPK)* yang merangkumi teknik *Proses Hirarki Analitikal (PHA)* untuk penilaian sebarang perisian. Batasan teknik *PHA* adalah ketidakupayaan untuk mengendalikan kriteria yang tidak menentu dalam proses penilaian membayangkan tidak ada rangka kerja penilaian yang memadai yang kini boleh digunakan untuk menilai *Pe-P* dengan lebih tepat. Ini kerana, kriteria dan sub-kriteria penting yang boleh digunakan untuk menilai *Pe-P* belum dikenal pasti secukupnya. Kajian ini cuba merumuskan rangka kerja penilaian yang dapat digunakan dengan secukupnya untuk penilaian *Pe-P*. Rangka kerja ini menggabungkan model kualiti *Pe-P* yang merangkumi kriteria penting untuk menilai *Pe-P*. Rangka kerja yang dibangunkan dalam kajian ini disokong oleh alat yang berdasarkan teknik *Proses Hirarki Analitikal Kabur (PHAK)* yang mampu menangani batasan *PHA*. Lebih daripada 250 artikel dan rujukan yang berkaitan dikaji semula untuk tujuan mengenalpasti kriteria utama untuk penilaian *Pe-P*.

Kajian Delphi telah dijalankan untuk mendapatkan senarai kriteria tambahan berdasarkan kesepakatan 31 pakar e-Pembelajaran tempatan. Sebanyak 11 kriteria dan 66 kriteria telah diekstrak dari tinjauan literatur manakala 16 kriteria tambahan telah disediakan oleh pakar. Secara keseluruhan, 11 kriteria dan 81 sub-kriteria telah disahkan oleh konsensus pakar. Berdasarkan ini, *Model Kualiti Perisian Bersepadu (MKPB)* kemudiannya dibina. Rangka kerja penilaian *Pe-P* menggabungkan *MKPB* dengan teknik *PHAK*, iaitu *MKPB-PHAK*, kemudian dirumuskan. Alat yang dipanggil e-LSO, kemudiannya dibangunkan untuk membantu dalam penilaian *Pe-P*. Penilaian kebolehgunaan e-LSO diuji melalui *Soalselidik Post-Study Kebolehgunaan Sistem (SPSKS)* yang melibatkan lima pakar *Pe-P*. Hasilnya mendedahkan bahawa para pakar berpuas hati dengan e-LSO dan mereka juga meluluskannya sebagai alat yang berguna untuk penilaian *Pe-P*. Secara keseluruhannya, boleh dikatakan *MKPB-PHAK* boleh menjadi panduan dan sokongan kepada organisasi dalam proses penilaian *Pe-P* mereka. e-LSO juga boleh membantu organisasi untuk membuat model keputusan mereka sendiri untuk penilaian *Pe-P* dengan mudah.

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LIST OF ABBREVIATIONS

ACC	Accuracy
ACP	Accessibility Control or Privilege
ADP	Adaptability
AHP	Analytical Hierarchy Process
AMI	Absolutely More Important
ANA	Analyzability
ASS	After Sales Support
BAR	Backup and Recovery
C	Criteria
CAGR	Compound Annual Growth Rate
CAP	COTS Acquisition Process
CAP-EC	CAP Execution Component
CAP-IC	CAP Initialization Component
CAP-RC	CAP Reuse Component
CD	Context Diagram
CFPR	Consistent Fuzzy Preference Relation
CHA	Changeability
CI	Consistency Index
CLR	Common Language Runtime
CMS	Contents Management System
COM	Community
CON	Conformance
COMM	Communication
COS	Cost Saving
COTS	Commercial of the Shelf Software

CR	Consistency Ratio
CSF	Critical Success Factors
CSP	COTS Selection Process
CUS	Customizability
DBMS	Database Management Systems
DBS	DBMS Standards
DEC	Development Cost
DEEC	Determine and Establish Evaluation Criteria
DFD	Data Flow Diagram
DEM	Demo
DesCOTS	Description, Evaluation and Selection of COTS Components
E	Experts
EI	Equally Important
ELI	Equally Less Important
e-Learning	electronic learning
e-LS	e-Learning Software
e-LSE	e-Learning Systematic Evaluation
e-LSO	e-Learning Software Option
ERD	Entity Relationship Diagram
EOU	Ease of Use
EPR	Error Preventing
ERP	Enterprise Resource Planning
ERR	Error Reporting
ESC	Educational System Change
ESD	Electronic System Decision
EW-LMS	Easy Way - LMS

EXP	Expansion
FAS	Fault Software
FAT	Fault Tolerance
FLE	Flexibility
FSR	Frequency of Software Release (FSR)
Fuzzy AHP	Fuzzy Analytical Hierarchy Process
GE	General Electric
GPL	General Public License
HAC	Hardware Cost
HYP	Hypermediality
ICT	Information Commucation Technology
IMC	Implementation Cost
INS	Installability
INT	Interoperability
IQR	Inter Quartile Range
ISO/IEC	International Standard for Organization/ International Electro technical Commission
ISQM	Integrated Software Quality Model
ISQM-Fuzzy AHP	Integrated Software Quality Model - Fuzzy AHP
IT	Information Technology
JE	Just Equal
LCMS	Learning Content Management System
LEA	Learnability
LEC	Learning Content
LEI	Learner Interface
LIC	Licensing Cost

LMS	Learning Management System
LOE	Length of Experience
MAC	Maintenance Cost
MAT	Maturity
MAU	Maintenance and Upgrading
MCDM	Multi Criteria Decision Making
MDS	Middleware Standard
MEC	Memory Capacity
MEdO	Malaysia Education Online
MGC	Marginal Cost
MKPK	*Membuat Keputusan Pelbagai Kriteria*
MKP	*Model Kualiti Perisian*
MKPB	*Model Kualiti Perisian Bersepadu*
MKPB-PHAK	*Model Kualiti Perisian Bersepadu - Proses Hirarki Analitikal Kabur*
MMU	Multimedia University
MOD	Modularity
MT	Method and Technique
OCH	Organizational Change
OCR	Organizational Resource
OCU	Organizational Culture
OPE	Operability
OPO	Organizational Politics
OTS	Off-the-Shelf
OTSO	Off-the-Shelf-Option
OUM	Open University

PB	Product Benefit
PBE	Past Business Experience
PE	Problem Encountered
PED	Pedagogical
Pe-P	*Perisian e-Pembelajaran*
PER	Personalization
PHA	*Proses Hirarki Analitikal*
PHAK	*Proses Hirarki Analitikal Kabur*
PORE	Procurement Oriented Requirements Engineering
PRE	Presentation
PSSUQ	Post-Study System Usability Questionnaire
PTR	Product/Technology Risk
RADC	Rome Air Development Center
REB	Resource Behavior
REP	Reputation
RET	Response Time
RI	Random Index
ROB	Robustness
RPF	Request for Proposal
RPL	Replaceability
RU	Risk and Uncertainty
SBE	Software Bugs and Errors
SC	Sub-Criteria
SCA	Scalability
SCS	SCORM Compliance
SEC	Security

SER	Services
SKP	Sree Knowledge Provider
SLA	Student/Learner Administration
SMI	Strongly More Important
SPSKS	*Soalselidik Post-Study Kebolehgunaan Sistem*
SPSS	Statistical Packages for Social Science (SPSS)
SQL	Structured Query Language
SQM	Software Quality Model
STA	Stability
STACE	Social-Technical Approach to COTS Evaluation
STD	Standardability
SUE	Systematic Usability Evaluation
SUI	Suitability
SUP	Support
SUT	Support Tools
TBS	Technical and Business Skills
TES	Testability
TFN	Triangular Fuzzy Number
TIB	Time Behavior
TICS	Technology Interaction Contents Services
TR	Technical Reports
TRA	Training
TRC	Training Cost
TRG	Troubleshooting Guide
TUT	Tutorial
ULA	User/Learner Administration

UNC	Unexpected Cost
UND	Understandability
UNITAR	University Tun Abdul Razak
UPC	Upgrading Cost
UPSI	*Universiti Pendidikan Sultan Idris*
USA	User Acceptance
USM	User Manual
USP	User Productivity
USS	User Satisfaction
VAS	Virus and SPAM
VER	Vendor Risk
VSI	Vendor Size
VSMI	Very Strong More Important
WLI	Weakly Less Important
WMI	Weakly More Important
WSM	Weight Score Method

CHAPTER 1: INTRODUCTION

1.1 Background

The increasing popularity of electronic learning (e-Learning) in recent years has encouraged organizations to implement the technology particularly, to support the teaching and learning process. In the business domain, e-Learning has been adopted as an alternative training method to improve the administration's efficiency. Training the staff to be well versed in e-Learning procedures is a step forward to fulfilling the current business trend which has to be adapted, if not, most businesses will not be able to survive. Through the use of the interactive learning approach, staff can be made more effective and more resourceful especially for organizations that are involved in business industries and academia (Chang, 2016).

Many countries in the world such as the United States of America as well as the European and Asian nations are adopting e-learning as a way to meet the increasing demands of modern commerce transactions as well as for higher education learning (Dorobat & Toma, 2015). A report by Ambient Insight, a United States-based international research company, noted a significant growth rate in the e-Learning market among Asian countries (Adkins, 2013; Adkins, 2014). It was found that Asian countries are experiencing the highest growth rate in e-Learning. In fact, seven of the top ten Asian countries with the highest e-Learning growth rates are Myanmar, Thailand, Malaysia, Vietnam, Indonesia, Nepal and Pakistan. Myanmar has the highest growth rate of 50.2% followed by Thailand with a growth rate of 43.7% while the growth rate of e-learning in Malaysia ranked third at 42.3%. This implies that even the third world countries are adjusting to current development by implementing e-Learning into their economy.

Among these Asian countries, Malaysia seems to stand out because there is an apparent growing interest in the implementation of e-Learning, particularly among Malaysian Universities, colleges, private institutions of higher learning as well as business organizations (Hussain, 2004). In the education domain, e-Learning is used in academic programmes to promote distance learning as well as to encourage independent learning among students. E-Learning has also become a resource tool for many lecturers who want to encourage and motivate their students to become more autonomous. Thus, e-Learning may also serve as a teaching technique for campus-based learning (Hussain, 2004). In this regard, teaching materials are uploaded and students need to access these materials before they can attend classes. Otherwise, these students may not be able to follow the respective courses in their academic programs.

Due to the advent of technology, the e-Learning approach has become a necessity for learning because it enhances the traditional teaching delivery method. Not only is e-learning more integrative as students have access to videos, pictures, quizzes, and materials to read and listen to, it is also more fun as e-Learning breaks the classroom monotony. It also develops students' confidence as they begin to be exposed to various learning channels. In this regard, e-learning enables instructors as well as students to become more motivated in their learning process. In the same way, when employees are required to acquire some knowledge in e-Learning, they too become more efficient and more driven into doing their job better as a result of what they had learnt in the teaching and learning process. When using the e-Learning approach, the teaching and learning process is conducted by accessing online educational/training programs instead of the students having to physically attend their classes or workshops. As long as there is a computer and a wi-fi accessible, e-Learning can be conducted anywhere in the world. This makes it very conducive for the individuals.

Over the years, e-Learning has become a popular approach for instructors to deliver their educational materials to their students, sometimes in advance so that students can review these materials beforehand. In higher institutions of learning such as colleges and universities, e-Learning has become a norm throughout the world (Bhuasiri et al., 2012) and Malaysia is not an exception. Associated with e-Learning is the Malaysia Education Online (MEdO) portal which is a national online learning portal that was launched in April 2011 with the objective of expanding distance learning internationally. One of the major goals of the e-Learning policy in Malaysia was to have at least 30% of all the courses offered in higher education to be delivered online by the year 2015 (Adkins, 2014).

Among some of the universities in Malaysia that are active in e-Learning are the Open University of Malaysia (OUM), Multimedia University (MMU), University Tun Abdul Razak (UNITAR) and *Universiti Pendidikan Sultan Idris* (UPSI). There are also some private organizations in Malaysia that offer e-Learning opportunities to their students and these organizations include the Sree Knowledge Provider (SKP) which had, thus far, developed fifteen online degree programs for its business management course (Adkins, 2014). This is beneficial to both the students and the college concerned because it is a win-win situation where students do not need to travel to the respective institutions to do their degree program and the college does not need to hire too many experts to run the program in classrooms. Despite its usefulness, there are also some serious considerations to e-Learning. For instance, the adoption of e-Learning into an organization’s existing curriculum needs to be contemplated with great care. This is because such an implementation would require the academic institution or organization to develop many other aspects of infrastructure so that e-Learning can be electronically operated. In other words, the organization needs to consider developing or customizing the e-Learning applications by using appropriate e-learning software (e-LS) (Nagi, 2006; Shee & Wang, 2008). These applications and implementations can cost money and require even more specific human resources who have to be specially trained. In 2014, the global market for e-Learning software (e-LS) products recorded a value of US$ 42.7 billion and the amount was expected to reach US$53 billion by the year 2018 (Adkins, 2014). Over the years since its invention, e-Learning needs are growing. Currently, the largest market for e-Learning Software or e-LS is the United States of America because it usually sets the trend for the rest of the world to follow. Following its footstep is the Asian market that is fast catching up because these Asian nations are becoming more resourceful and more innovative. The e-LS market for the Asian region was projected to be moving from US$7.9 billion in 2013 to US$12.1 billion by the year 2018 (Adkins, 2014).

Although e-Learning may come across as a common and current teaching and learning approach, there are many varieties of e-LS to be used in the e-Learning application. For example, there is the Learning Management System (LMS), Content Management System (CMS) and Learning Content Management System (LCMS) (Kapp, 2003; Itmazi et al., 2005; Nagi et al., 2008) which have been utilized by various countries for their own benefits. In general, the e-LS is the software application which, when used, must provide support for the teaching and learning process that is conducted via e-Learning (Costa et al., 2012). The e-Learning process must encompass several stages which include creation, organization, storage, delivery, access to and use of learning resources, lesson planning, assessment, progress tracking, personalization of the learning experience, collaboration and communication (Costa et al., 2012; Dorobat & Toma, 2015).

Despite its benefits, the investments made to acquire the e-LS acquisition can be significantly costly (Adkins, 2014). The wrongful selection of an e-LS variety can be detrimental to the organization since the costs involved may run into thousands of dollars (Michael & Week, 2014). The cost for an e-LS includes set-up fees, salaried time for the training of staff and costs for substitute teachers during a professional development of the educators. Depending on the size of the coverage for the e-LS selected, the costs of setting up an e-Learning approach can add up from ten to twenty thousand dollars or more (Michael & Week, 2014). Nonetheless, the growing demand of the e-Learning market has seen a significant increase in the number of suppliers who are also working hard to upgrade their current software or to produce new e-LS products for the respective organizations (Adkins, 2013). Among the fastest growing e-LS that is being used is the Learning Management System (LMS) which was set up in 2009 (Bersin et al., 2009). It also represents a huge portion of the world's market. It has been reported that more than US$860 million in the world market is made up of more than 60 different providers and vendors.

The LMS market is said to be worth US$7.83 billion by the year 2018 (Marketwired, 2013; Trends, 2014). The success of the e-Learning implementation, for any organization, depends heavily on the evaluation process of selecting the most suitable e-LS. With the rapid increase noted in the number of e-LS products available currently, there is now also a challenge for organizations to select the most suitable e-LS for their organizations. However, the issue may be compounded by the fact that the evaluation task of the e-LS can be difficult for most organizations because each e-LS product offers different components that fulfil different tasks needed by the organizations (Shee & Wang, 2008). Thus, it is important for any organization who wants to implement the e-LS to take more caution in evaluating the e-LS that is desired by focusing on its own needs so as ensure that the investments made for the e-LS implementation would not be wasted.

The evaluation process of a software product is a complex task because it involves many processes (Jadhav & Sonar, 2009) which include:

i. Planning the evaluation and requirement definition;
ii. making preliminary investigation;
iii. Establishing the evaluation criteria;
iv. Shortlisting of software;
v. Evaluating of software;
vi. Selecting of software;
vii. Negotiating with vendor, and
viii. Purchasing of software.

With these numerous processes and activities involved, the evaluation process of the software product, the e-LS, can be complicated as well as time consuming. The evaluation process for the selecting the appropriate and correct software for use, can nonetheless be achieved by using a set of predetermined evaluation and selection guidelines (Van Staaden, 2008). This will serve as a standard procedure that can be used in the evaluation process of the software product. The ISO/IEC 14598 had mentioned that thus far, the series of standards which also serve as guidelines for organizations to use when implementing the evaluation for the software product (ISO/IEC 14598-1, 1999) selected, is still inadequate. As a result of the lack of a proper and effective evaluation system that can be used to evaluate the e-LS, many organizations seem to have made large investments on poor product choices (Lawlis et al., 2001). In most of the e-LS evaluation process, a Software Quality Model (SQM) approach is usually applied. This is to access the criteria, definitions and descriptions of the software. In this regard, the SQM can be used to evaluate the quality of the software products

(AL-Badareen et al., 2011). Some examples of the SQM approach can be traced to McCall's Model (McCall et al., 1977), Boehm's Model (Boehm et al., 1978) and Dromey's Model (Dromey, 1995). The ISO/IEC 9126-1 Quality Model also provides a set of criteria to be considered in the evaluation and selection process and they include *Functionality, Maintainability, Usability, Reliability, Portability* and *Efficiency* (ISO/IEC9126-1, 2001).

Apart from the SQM approach, the commercial Off the Shelf (COTS) evaluation framework may also be used for software evaluation and selection. The COTS software approach is made up of commercial pieces of reused software which were developed and supported by outside vendors (Tarawneh et al., 2011). The COTS software can be integrated and reused by other software projects (Tarawneh et al., 2011). The COTS software not only provides the criteria that can be used to evaluate the e-LS; it also outlines the process as a guideline for organizations to use when making an evaluation of the e-LS software. The criteria used by the COTS approach include *Cost, Vendor, Product Benefit, Organizational* and *Risk and Uncertainty* and these criteria are often located in COTS studies. These criteria are considered to be important for the evaluation process. For instance, the *Cost* criteria is important because it would be constrained by the financial commitments of the organization, therefore this criteria needs to be included in the evaluation process (Carvallo & Franch, 2006; Du et al., 2013). Serving as a guideline for the evaluation process of the software, several COTS selection methods have been proposed for the COTS framework. This is noted in many kinds of literature (Kontio, 1999; Ncube & Maiden, 1999; Kunda & Brooks, 1999; Och et al,, 2000). Nonetheless, thus far, there is no appropriate COTS method which has been accepted as a standard framework that can be used for the COTS evaluation and selection process (Gupta et al. 2013). In his study, Ruhe (2003) summarized the COTS evaluation and selection process into six stages which include:

i. Define the evaluation criteria based on the requirements and constraints;
ii. Search for the COTS products;
iii. Filter the search result based on requirements;
iv. Evaluate the COTS alternatives on the shortlist, and
v. Analyze the evaluation data.

These stages consist of the general process for COTS evaluation. The current study, in attempting to develop an evaluation framework, hopes to show that an evaluation framework that contains a process is a better guideline that could be used to support the organization's e-LS evaluation procedure since such a framework is currently not available. Similar to the other software, the e-LS may also be a difficult system to evaluate because many levels of processes are involved and the evaluation criteria may also be complicated as they range from main criteria to sub-criteria to sub-sub criteria. A suitable evaluation framework that can enable organizations to evaluate these criteria and sub-criteria of the e-LS would have been an important discovery. Nonetheless, more may be churned out from this study as it attempts to fulfil its objectives and so develop a good evaluation guideline that can be used to support the many organizations' e-Learning implementations.

As has been noted, most of the software evaluation approaches applied the Multicriteria Decision Making (MCDM) technique which includes the Analytical Hierarchy Process (AHP). This technique suggests a sequence of process as a guideline for organizations to evaluate and select the software that will be used by the respective organizations. The

AHP technique, however, relies on the pairwise comparison of two different 'subjects' to evaluate the criteria during the evaluation process (Mohamed et al., 2007). One limitation noted in the AHP is that it is unable to address the uncertain characteristics when making a judgment since it relies on crisp or exact numbers to evaluate the criteria, thus it is unable to decipher any uncertain numbers (Mohamed et al., 2007; Zaharias et al., 2002). To overcome this limitation of the AHP technique, the Fuzzy AHP technique is applied (Catak et al, 2012). Nevertheless, this Fuzzy AHP technique only uses mathematical calculations, hence, it may create other forms of complexity when conducting and calculating the evaluation of the e-LS manually.

In the attempt to answer the research questions which were specifically formulated for this study, a noteworthy e-LS evaluation framework that also contains a sequence of processes needs to be developed so that this can be used as an appropriate technique that is accompanied by a relevant tool to support the evaluation process of the e-LS. This framework that is developed can then be used by organizations as a systematic guideline that not only adequately but accurately supports and assists in the evaluation of the e-LS. This framework could facilitate the evaluation process for any selection of a suitable e-LS based on the needs of the organizations concerned.

1.2 Problem Statement

Currently, there is no standard evaluation framework which consists of a series of evaluative processes as well as a list of evaluation criteria and sub-criteria that can be used as an adequate evaluation technique and tool as guideline to support organizations in evaluating the e-LS adopted. Thus makes the selection of suitable e-LS a difficult task.

The outcome drawn from this evaluation framework that is developed will be able to show the respective organizations whether the e-LS which they have adopted is effective and if so, why. The outcome drawn from the evaluation framework can enable organizations to select or acquire the most suitable e-LS for use rather than to make some bad investments. The current lack for such an evaluation framework as desired by this study, creates a model gap and this gap may be attributed to the many issues and processes involved in a mere evaluation exercise, as mentioned above.

The Existing Software Quality Model (SQM) and the COTS software framework are currently available for use. However, they do not provide sufficient criteria that are important in the evaluation process of the e-LS. In this regard, organizations may face difficulties in identifying the relevant criteria based on their needs to implement the e-LS. The SQM, like the ISO/IEC 9126-1 Quality Model, is commonly used to evaluate the quality of some software products (Behkamal et al., 2009). This particular framework consists of certain evaluation criteria which have been provided by the ISO/IEC 9126-1 Quality Model and they include *Functionality, Maintainability, Usability, Reliability, Portability* and *Efficiency*. Likewise, the COTS software evaluation framework also provided some evaluation criteria that are important for the evaluation process. Among the criteria listed are *Cost, Vendor, Product Benefit, Risk and Uncertainty* and *Organizational*.

However, since these criteria reflect the general characteristics only, the ISO/IEC 9126-1 Quality Model as well as the COTS software, need to be refined before either can be used to evaluate any other sophisticated software (Botella et al., 2004). Chua and Dyson (2004) have also emphasized that the ISO/IEC 9126-1 Quality Model model does not provide enough criteria for the evaluation of the teaching and learning components noted in the e-Learning system. Therefore, the outcome of the e-LS would be affected when it is implemented. There are several differences between the e-LS and other software based on its nature as educational software. Among the criteria listed, the ones that are unique to the educational purpose and which need to be included in the evaluation process are the criteria of *Pedagogy, Adaptivity* and *Personalization,* especially for the purpose of evaluating an e-Learning systems or applications that is geared for a university. The implementation of the e-LS by any organization must also be at a reasonable price or cost in order for organizations to be able to implement the system as well as benefit from the money that have been invested in it. Therefore, an evaluation that avoids the evaluation criterion of *Cost,* for example, during the evaluation process, may be risky and detrimental to the organization. As such, a comprehensive e-LS evaluation criteria needs to be developed so that these can be carefully compiled and used as a guideline to evaluate the e-LS product so as to enable organizations to arrive at a precise and correct decision.

To date, it appears that an adequate guideline that comprises a sequence of processes that can be used by organizations to make an accurate and precise evaluation of the e-LS they wish to adopt is still lacking. This lack can be attributed to the complex evaluation procedure for a software and the many complex processes that are involved (Jadhav & Sonar, 2009). Although literature (Jadhav & Sonar, 2009) suggests that these processes should be general in nature, they must also cater to the needs of the respective organizations which may have different aims and goals from each other. A good evaluation guideline should be able to highlight to the respective organizations, the differences or inconsistencies of the e-LS being implemented. However, these discrepancies should be detected in stages so that the procedure is easy for the organizations to follow. A good evaluation procedure is likely to be tedious and complex as it involves the evaluation of the main criteria and other sub-criteria involved. Thus, it has to be one that can be easily adapted by organizations so that several appropriate alternatives to evaluating the e-LS are accessible.

In the preliminary survey conducted of experts, responses showed that experts noted that there was a lack of a desirable guideline or standard procedure which they could follow in evaluating the e-LS they wish to adapt. Consequently, it became a challenge for these organizations to evaluate the e-LS software adequately and accurately. In this regard, it is possible that previous e-LS software evaluation methods or techniques adopted by the organizations have been unsuitable or even inadequate. As a result, those evaluation reports which they had created may contain several inadequacies due to some aspects of the criteria being overlooked and not captured by the conventional evaluation guideline. As a result, the respective organizations may experience many problems with their e-LS.

A review of past studies (Grau et al., 2004; Cavus & Ala'a, 2009) focusing on the e-LS evaluation noted that a number of tools such as the Description, evaluation and selection of COTS components (DesCOTS) and Easy Way LMS (EW-LMS) had been introduced but these tools may only be suitable for a specific set of e-LS implementation and inapplicable to others. Currently, there are many varieties of the e-LS and due to this widespread use of the e-LS, it is important that a more sophisticated evaluation tool be developed to meet the demands of the varieties of e-LSs available. Moreover, it has been noted that the current existing tools are unable to offer a comprehensive evaluation of the criteria and sub-criteria, both of which are important to the organizations in making the right selection of an e-LS. Thus far, the MCDM technique such as the AHP is commonly applied in the evaluation of the e-LS by organizations but the AHP technique has limitations. It is unable to evaluate any uncertain criteria present in the software although studies (Tang & Beynon, 2005) have suggested using the Fuzzy AHP technique as an alternative. In their study, Liu et al. (2009) utilized the Fuzzy AHP technique to evaluate an e-LS. The evaluation was manually conducted through the support of a questionnaire survey. Their study did not meet the requirements of the Fuzzy AHP technique because a manual approach was conducted instead. This approach was not practical since the Fuzzy AHP technique involves many steps and criteria. Moreover, the Fuzzy AHP technique also requires pairwise comparisons that involved complex mathematical calculations. Based on this, it is deduced that the Fuzzy AHP technique may be relevant but it may not be able to fulfill the relevant needs of the respective organizations. Therefore, developing the appropriate tools for the Fuzzy AHP technique is necessary not only to support the evaluation process but also to enable the technique to store information about the e-LS evaluation criteria, sub-criteria and e-LS.

1.3 Research Objectives

Based on the above gap as highlighted in the problem statement, the research objectives of this study are:

i. To investigate the limitations of the current practices noted in the evaluation and selection of the e-LS.

ii. To formulate a comprehensive ISQM-Fuzzy AHP evaluation framework that is adequate for the e-LS evaluation.

iii. To develop a tool based on the ISQM-Fuzzy AHP evaluation framework by using evolutionary prototype approaches.

iv. To evaluate the usability of the tool in an e-LS evaluation by using the Post-Study System Usability Questionnaire (PSSUQ).

1.4 Research Questions

To fulfill the objectives of the research, the following research questions are formulated:

i. What are the limitations on the current process of evaluating and selecting the e-LS?

ii. How is the ISQM-Fuzzy AHP evaluation framework formulated for the e-LS?

iii. Based on the ISQM-Fuzzy AHP evaluation framework, how is the tool developed for the e-LS evaluation by using evolutionary prototyping approaches?

iv. How is the usability of the tool be evaluated for the e-LS evaluation by using the PSSUQ ?

1.5 Scope of Study

The scope of this study covers:

i. The evaluation and selection of the e-LS by organizations in Malaysia.

ii. The criteria in the proposed ISQM which are based on those identified from the literature and also those validated by experts comprising Technical Experts, Decision Makers and Academicians/Researchers.

1.6 Research Methodology

The research methodology applied in this study comprises four phases as shown in Figure 1.1

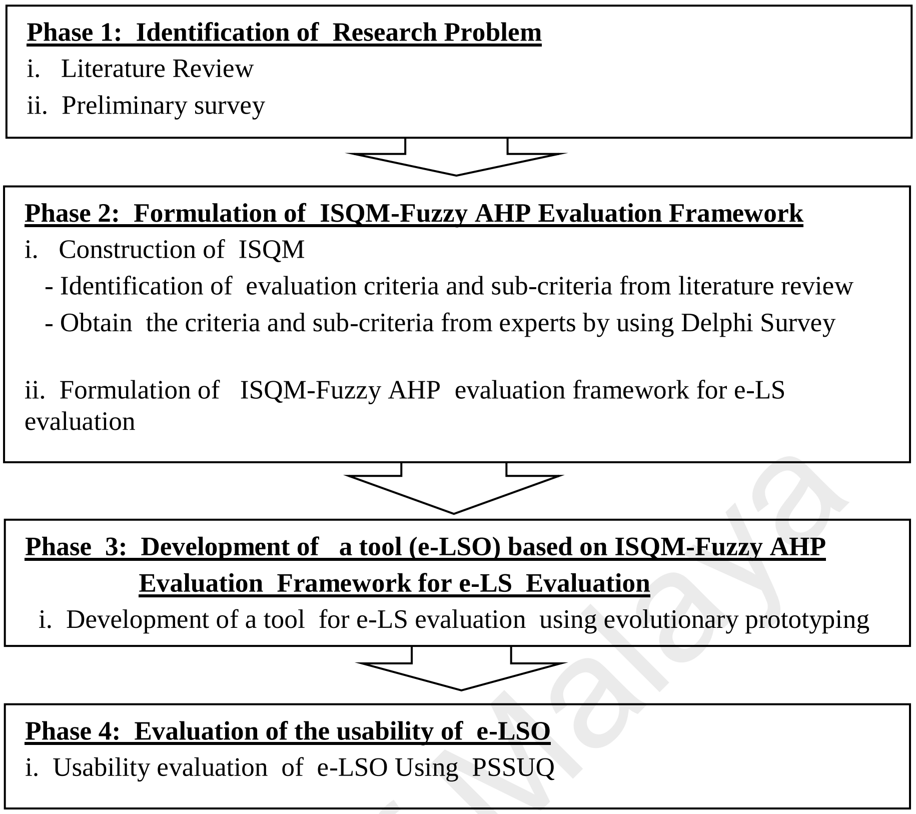

Figure 1.1: Research Methodology Processes

a. Phase 1: Identification of the Research Problem

In Phase 1, the research problem was identified by reviewing current and past literature. Together with this, a preliminary survey was also conducted on 50 experts who were Technical Experts, Decision Makers as well as Academicians/Researchers from various organizations. The aim of the survey was to understand the current practices of the e-LS evaluation and its selection process in the context of Malaysia. It also aims to obtain the relevant information of experts which encompass the experts' background, the implementation of the e-LS in their respective organizations, the stages and methods used in the evaluation and selection of the e-LS implemented, the evaluation criteria used for the e-LS implemented and the tools used in the evaluation of the e-LS. In phase 1, the limitation of the current process of evaluating and selecting the e-LS was determined.

b. Phase 2: Formulation of the ISQM-Fuzzy AHP Evaluation Framework for e-LS Evaluation

Phase 2 consists of three steps namely:

Step 1: Identification of the evaluation criteria from literature

The evaluation criteria were obtained from the literature review as well as from the groups of experts' consensus. A list of suitable evaluation criteria for the e-LS, their definitions and metrics were initially identified from the literature review. Two Delphi survey were then administered so as to obtain any additional criteria and to obtain the consensus of the experts towards the criteria and sub-criteria identified.

Step 2: Construction of the ISQM for the e-LS evaluation

An ISQM was constructed for the e-LS evaluation by using the criteria taken from the ISO9126-1 Quality Model with additional sub-criteria acquired from Step 1. An integrated software quality model was then developed based on these cumulative criteria.

Step 3: Formulation of the ISQM-Fuzzy AHP Evaluation Framework for the e-LS Evaluation.

Here, the ISQM-Fuzzy AHP evaluation framework was formulated and constructed by consolidating the ISQM and the Fuzzy AHP. The framework consist of a sequence of processes which were defined by using the Fuzzy AHP technique as a guideline. The evaluation framework recommended the use of a tool to assist in the e-LS evaluation process.

c. Phase 3: Development of a Tool (e-LSO) Based on the ISQM-Fuzzy AHP Evaluation Framework for e-LS Evaluation

In Phase 3, the tool that can assist in the e-LS evaluation, that is, the e-Learning Software Option (e-LSO) was developed. This was based on the ISQM-Fuzzy AHP evaluation framework. The evolutionary prototyping approaches were applied in the development of the e-LSO.

d. Phase 4: Evaluation of the Usability of the e-LSO

In Phase 4, the evaluation of the usability of the e-LSO was conducted. This process involves five (5) e-LS experts. These experts were required to fill in a questionnaire which was developed based on the PSSUQ so as to obtain their evaluation on the usability of the e-LSO. They were also required to answer several questions for future improvements of the e-LSO.

1.7 Significance of the Study

The significance of this study are as follows:

i. A report by organizations using the e-LS in Malaysia detailing their current practice and needs for the evaluation and selection of an e-LS can be obtained.

ii. The participation of various experts made up of Technical Experts, Decision Makers and Academicians/Researchers involved in e-Learning can provide a more comprehensive and accurate result that can be used to develop an evaluation guideline which can be used by organizations to identify and validate their e-LS evaluation criteria and sub-criteria based on organization needs.

iii. The construction of an ISQM that integrates important evaluation criteria for the e-LS evaluation that has been validated by experts;

iv. The formulation of the ISQM-Fuzzy AHP evaluation framework which consists of several processes and relevant evaluation criteria for the e-LS evaluation;
v. The Implementation of the ISQM and ISQM-Fuzzy AHP framework in the e-LS evaluation; and
vi. The development of the e-LSO based on the ISQM-Fuzzy AHP evaluation framework which can be used by organizations in the evaluation of the e-LS implemented.

1.8 Organization of Thesis

This thesis is composed of eight chapters and it is organized as follows:

Chapter 1 focuses on the introduction of this study. This chapter presents the background of the study, the problem statement, the objective of the study, the research questions, the research methodology and the significance of the study.

Chapter 2 reviews current and past studies which are pertinent to this study. The literature review covers the background of the e-LS and the various types of e-LS, the evaluation and selection process of software products, software evaluation and selection techniques and software tools for evaluating software products. The chapter concludes by highlighting the relevant research gap in this area.

Chapter 3 covers the research methodology. This chapter discusses the research process, the instruments used, the data collection process and the data analysis involved to complete the study.

Chapter 4 presents the results acquired from the preliminary survey which was aimed at obtaining information that would highlight the current practices of evaluating and selecting the e-LS by organizations. This chapter will also reveal the limitations noted in the e-LS software evaluation and selection process.

Chapter 5 discusses the identification of the evaluation criteria and the construction of the ISQM for the e-LS evaluation. As mentioned above, the evaluation criteria were obtained from current and past literature as well as the criteria which have been validated by the selected experts' consensus. The evaluation criteria of the e-LS were then consolidated to construct the ISQM. Finally, the ISQM-Fuzzy AHP evaluation framework that can be used for the e-LS is further elaborated in the chapter.

Chapter 6 discusses the development of the e-LSO which can support the e-LS evaluation process by using an evolutionary prototyping approach. The e-LSO architecture, modules, design and interface are also explained. This chapter summarizes the evaluation process, criteria and technique used.

Chapter 7 presents the usability evaluation of the e-LSO. The results of the usability evaluation of the e-LSO are also discussed in this chapter.

Chapter 8 concludes the research work. The chapter also provides the contribution and limitation of this study as well as recommendations for future work in the same research topic.

1.9 Summary

This chapter has presented the introduction to this research by providing the background of the research where the purpose of the research was also highlighted. The research problem was then emphasized and based on the research problem, the research objectives were highlighted. In order to accomplish the research objectives, five research questions were formulated. This was followed by the scope of the research and the research methodology. The significance of the research was mentioned followed by the organization of the thesis. The next chapter will review related works linked to this research.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

Chapter 2 reviews the literature and the past works pertinent to this study. In general, this chapter covers the literature review on e-Learning and e-Learning software, the evaluation and selection process of the software, the software evaluation models and their frameworks as well as the software evaluation techniques. Several studies focusing on e-Learning software evaluation model and framework are also examined. The existing tools used for software evaluation will also be emphasized before the issues and gaps motivating this study are highlighted.

2.2 e-Learning

E-learning or electronic learning refers to computer-enhanced or technology enhanced learning (Behera, 2013). It describes learning through a variety of information technology development including the Internet, networking and computers (Treven & Zizek, 2007). E-Learning is the evolution of distance learning; it creates, fosters, delivers and facilitates the learning process for a learner virtually and so teaching and learning can occur at anytime and in any place supported by the interactive networks of technology (Liu et al., 2009). Based on the definition given to e-Learning, it can thus be seen or understood that e-Learning is a technology that can be used to support the acquisition of knowledge and skills by merely using the necessary learning applications which have been supported and enhanced by computer facilities and networks.

The benefits of e-Learning are:

i. Learning Flexibility: e-Learning is flexible for the instructor/trainer and learner as it can be conducted in any location that is equipped with computers and an Internet connection. Thus teaching and learning can occur at homes, workplaces and Internet cafes (Cavus, 2010).

ii. Cost Saving: Organizations could save money and employee time by providing on-the job training through e-Learning (Tzeng et al., 2007).

iii. Group collaboration: Electronic messaging creates new opportunities for groups to work together by creating shared electronic conversations and discussions (Liaw, 2008).

iv. New educational approaches: Online courses provide opportunities for teachers and learners to share innovations in their own works with the immediate support of electronic groups (Liaw, 2008).

2.3 e-Learning Software

The e-Learning software (e-LS) is a software that can be used to customize or develop e-Learning applications for e-Learning implementations (Shee & Wang, 2008). Based on the literatures, the e-LS can be categorized into 3 platforms and developed using various software deployment tools, as shown in Figure 2.1.

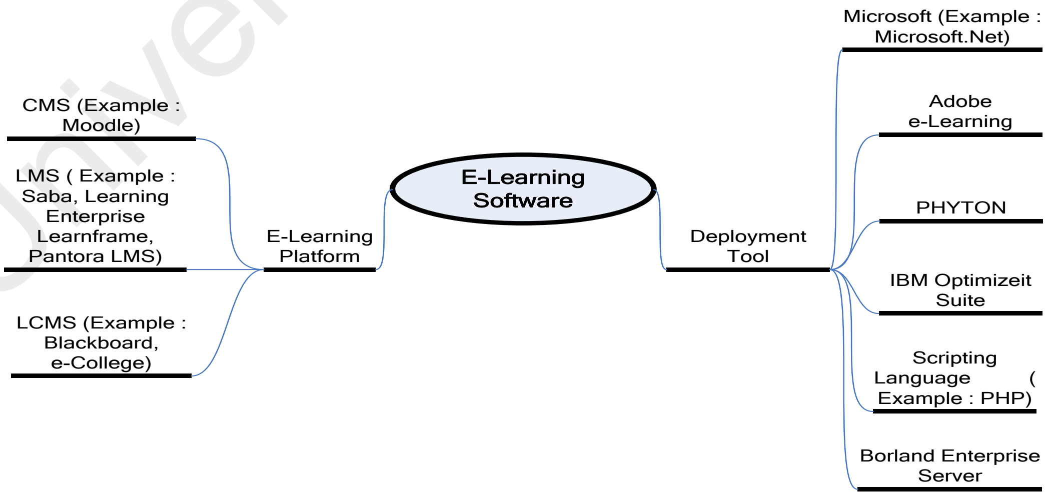

Figure 2.1: The Categories of e-LS

According to Nagi et al. (2008), the e-LS product can be open source software products or they can be commercially developed software products.

a. Open Source

An open source software is one that has to be referred to the software's source code. This software is freely available to anyone who wishes to extend, modify and improve on the code (Koohang & Harman, 2005). Examples of open source software packages are Moodle, Illias, Dokeos, eFront and Sakai which can be downloaded free from their respective websites.

b. Commercial

Commercial e-LS products are designed and developed for sale to the general public. Examples of the commercial e-Learning software are Blackboard, WebCT, DesireLearn and eCollege.

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2.3.1 e-Learning Platform

The e-Learning platform is a digital media technology which emphasizes on using technology to transform and guide education (Zhao, 2011). The platform is a software-controlled learning infrastructure that attempts to emulate what teachers do in a face-to-face classroom environment. It is also an emerging tool for corporate training (Fresen & Boyd, 2005). The e-Learning platform is provided with digital resources that are delivered through the network provided that the Internet and the accessing equipment are accessible (Gumińska & Madejski, 2007). Users can use these resources for teaching and learning and it focuses on the concept of Anyone, Anytime, Anywhere and Any-device. The e-Learning platform is characterized by its integrative nature and its openness in accommodating all types of people and customers and it can also fulfil the various needs of organizations (Zhao, 2011). The functionality of the e-learning platform typically includes access to learning contents and tests, communication and collaboration tools for students and course management and assessment facilities for instructors (Kats, 2010). The e-learning platform may also include administrative functions or interfaces which allow for an administrative system that can be used to manage student admissions and enrollment as well as resource planning and accounting purposes (Kats, 2010). The e-Learning platform offers users a type of integrated tools and services for teaching, learning, communicating, and managing the learning materials and this is exemplified by the Learning Management System and the Learning Content Management System.

The e-Learning platform can also be used to develop e-Learning systems or applications. This has been verified by Nagi (2006) who noted that e-Learning systems are software which organizations use for customizing contents with less programming needs. The e-learning system has been recommended as an alternative learning resource for students who are ready for distance learning (Gumińska & Madejski, 2007). Therefore, the main tasks of the e-Learning platform is to: Provide students with information about the available courses, the enrollment procedure for a course, the rules of using the platform, subject approval policies, the procedure for acquiring certificates after completing a course, offer potential students the possibility of declaring their intention to participate in the course over the Internet, provide education, providing access to the educational materials, make the communication between the administrative personnel and the students easier, and enable lecturers to be contacted with ease (Gumińska & Madejski, 2007).

The e-Learning systems or applications can be developed by using the following types of platforms:

a. Content Management System (CMS)

The CMS is a combination of a large database, file systems and other related software modules which are used to store and retrieve huge amounts of data later (Islas et al., 2007). Thus, the CMS can also be used to construct e-Learning applications. The CMS can also be used to create information portals. These portals act as the backbone of data management which are based on a pre-written template that acts as a platform for each page in the site while those pages are being created (Islas et al., 2007). Examples of the CMS are Joomla and Mambo.

b. Learning Management System (LMS)

The LMS is a software application that is made up of a set of tools for online teaching and learning (Cavus & Ala'a., 2009). The LMS acts as the platform for a web-based learning environment through an enabling process which tracks the course management by means of looking at its delivery; it also tracks the learning and testing process; it has facilities to enhance communication between the parties concerned and it also monitors other administrative duties such as the registration process and scheduling (Cavus, 2010). The LMS integrates all the aspects of managing on-line teaching activities (Colace et al., 2006) and its main focus is to manage learners and to keep track of their progress and performance across all types of training activities. The e-Learning educators only need a minimum level of technical knowledge to be able to efficiently develop an e-Learning environment. Collaborations with Information Technology (IT) specialists are often not necessary (Islas et al., 2007). Through the e-Learning platform, instructors and learners no longer have to be physically present in the same location. Examples of the LMS system which are currently in use include Moodle, Claroline and ATutor.

c. Learning Contents Management System (LCMS)

The LCMS offers services which allow content management to be monitored as well as paying particular attention to how the contents were created, imported and exported (Colace et al., 2006). The LCMS is a multi-user environment that allows the learning developer to create, store, reuse, manage, and deliver the digital learning contents which have been acquired from a central object repository (Horton & Horton, 2003). The LCMS includes all the functions that are necessary for the creation, description, importation or exportation of contents as well as their reuse and sharing (Colace et al., 2006).

The main features of the LCMS are associated with content management, from the production of the contents until the storage. it also includes the reusability and distribution of the contents. The LCMS encourages learners to adopt the personalized learning technique and it also helps organizations to reduce the distance between the tool development and the LMS. In addition, organizations and academic institutions can assess their learning needs through the LCMS besides the ability to incorporate e-learning solutions (Horton & Horton, 2003). Examples of the LCMS are Blackboard and e-college.

The e-Learning systems or application can also be developed using a deployment tool.

2.3.2 Deployment Tools

The Deployment tools are actually a type of software that can be used to develop web based applications including e-Learning applications. For example, Java can be used to develop e-Learning applications (Drigas et al., 2006) so can other deployment tools such as Microsoft.Net, JSP.Net, Borland Enterprise Server and PHP (Hypertext Processor). The deployment tool can enable organizations to develop specific e-Learning systems or application of e-Learning in their organizations based on scratch.

a. Microsoft.Net

The Microsoft.net or .NET Model is a software model developed by Microsoft. The software primarily runs on Microsoft Windows and it includes a large library which provides language interoperability across several programming languages. Developers may produce the software by combining their own source code with the .NET Model and other libraries. Programs written for the .NET Model are executed in a software environment which is known as the Common Language Runtime (CLR). It is a virtual machine application that provides services such as security, memory management, and exception handling. Microsoft also produces an integrated development environment particularly for the .NET model called Visual Studio.

b. Borland

Borland has a range of powerful component-based development solutions. These solutions were designed to take over the application model and to quickly create the final application, leveraging the features of the underlying infrastructure platform. Borland's solution was designed to help users to deliver their applications faster, reduce development costs and increase business responsiveness. Examples of Borland's software products are Borland Enterprise Server, Borland JBuilder, Borland C#Builder and Borland InterBase (Lee, 2004).

c. PHP

The PHP was originally created by Rasmus Lerdorf in 1994. The reference implementation of PHP is now produced by the PHP Group (Lerdorf et al., 2006). The

PHP is a server-side scripting language that is designed to be used for web development and as a general-purpose programming language. It is a free software that is released under the PHP License. However, the PHP license is incompatible to the General Public License (GPL) due to restrictions on the usage of the term PHP. Nonetheless. the PHP can be freely deployed on most web servers and also as a standalone shell on almost every operating system and platform. The PHP codes are interpreted by a web server with a PHP processor module which generates the resulting web page. The PHP commands can be directly embedded directly into an HTML source document rather than calling an external file to process data. It has also evolved to include a command-line interface capability and this can be used in standalone graphical applications.

The above review shows that there are many e-LS products available in the market place. They include the CMS, LMS, LCMS and other deployment tools. These can be open source products or commercial products and so most organizations have many options in the procurement of the e-LS for their e-Learning implementations. The success of an e-learning implementation depends on the right choice of the e-LS that meets their correct needs (Kapp, 2003). In this regard, making an accurate and precise evaluation and selection of the e-LS is important for organizations. The correct choice of the e-LS saves time and cost for the organizations concerned, thereby, easing the minds of the end users.

2.3.3 The Importance of Evaluating and Selecting a Suitable e-LS

The implementation of the e-Learning among organizations can provide many benefits such as learning flexibility, cost saving, self-learning, group collaborations as well as a new and innovative approach to learning within the education domain. However, the acquisition of a suitable and appropriate e-LS for the implementation of e-Learning, can be very costly; it can consume organizations a significant portion of their financial budget (Adkins, 2014). The e-LS is one type of COTS software product. The commercial application package or the COTS strategy that is to be embedded within a system development is very extensive (Whitten et al., 2004). In fact, the production of e-learning applications has created a lot of confusion for decision makers when they have had to make a decision on the selection of alternative e-LS products (Shee & Wang, 2008).

The e-Learning implementation can come from various e-LS products, whether they are CMS, LMS, LCMS or deployment tools. However, the organizational needs for a particular e-LS depend on the users of the e-LS who are the e-Learning developers and the end-users. The e-Learning developers use the e-LS to customize or develop the e-Learning application. The end-users which may include students, teachers, and the e-learning administrators, would be using the e-Learning applications for their educational and administrative needs. Besides these, it is also important to consider the needs of the organization's strategic planning such as the cost effectiveness or the benefits of the e-LS adopted and the e-Learning implementation (Macpherson et al., 2005). As a result of this, organizations have no choice but to consider the many criteria that are important for them when evaluating the e-LS based on their respective needs.

2.4 Evaluation and Selection Process of Software

Due to the many choices of software that are available in the market, one effective and standard guideline to be used for the evaluation and selection process is needed. The evaluation of a software is defined as the assessment of the software criteria according to specified procedures (Kontio, 1996). The selection of the software is a process of making choices among the different products available (Pollock & William 2007). The evaluation and selection process of a software consist of several stages which have been designed and intended as a guideline to be adapted according to the requirements of the individual organizations (Jadhav & Sonar, 2011). Jadhav and Sonar (2009) emphasized that there are many processes involved in the evaluation and selection of a software. These processes are considered as difficult because it contains many stages. Figure 2.2 illustrates the stages involved.

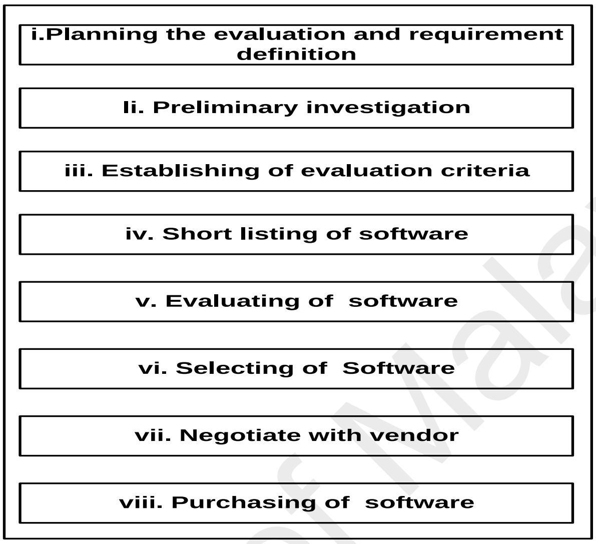


Figure 2.2: The Stages in the Software Evaluation and Selection Process

2.4.1 Planning the Evaluation and Requirement Definition

The first stage of the evaluation and selection process is to plan the evaluation and to define the requirement. This is considered and important first step in the early stage of the process (Van Staaden, 2008). Organizations needs to detail out their requirements otherwise it would affect the final outcome of the evaluation and selection (Davis, 1989). This process may involve individuals or a group of staff who are responsible in the decision making processes (Hunt & Westfall, 2003; Lai et al., 2002; Bandor, 2006). The requirement definition process covers the following items:

i. Managerial requirements such as budget, time and reporting requirements;
ii. Functional requirements such as stated business needs and technical requirements;

iii. Technical requirements such as data flow diagrams (DFD), system interfaces, hardware and network.

In this process, the user community and other key stakeholders would collaborate with the acquisition team in identifying the organizations' needs and the software requirements expected (Hunt & Westfall, 2003). Romney et al. (2012) highlighted that the following strategies could also be used whether by individually or in combination with many others when in the requirement definition stage:

i. Surveying end-users to determine their requirements using questionnaires, personal interviews and focus groups;

ii. Analyzing the existing system and eliminating requirements that have already been defined;

iii. Examining how existing software is being used and what its impact is so as to determine the shortcomings of the system and to identify any new requirements needed by the users; and

iii. Piloting a demonstration of the software when there is a problem in identifying the requirements.

Based on this, it can be said that the requirements identified must be complete and accurate for these to be used in the evaluation and selection of the most appropriate software package.

2.4.2 Preliminary Investigation

The second stage is the preliminary investigation. At this stage, the project team conducts a preliminary investigation on the availability of the software packages. The activities include investigating the potential software package availability, the major functionalities of the software and the features that are supported by the software package (Jadhav & Sonar, 2009). The web based resources could be used in this preliminary investigation stage, for example, the vendor's web site, product pamphlets, professional association catalogues and other third party reports.

2.4.3 Establishing of Evaluation Criteria

The third stage involves establishing the evaluation criteria which have been identified in the early stages of the evaluation process (Davis, 1989). The evaluation criteria are constructed with clear definitions and they will be used in the evaluation process. Kontio et al. (1996) stated that criteria such as *Reliability*, *Maintainability* and *Portability* are then developed after the requirements have been identified. However, some researchers (Chen et al., 2005; Lee et al., 2000) recommend that the establishing of the evaluation criteria be done by analyzing features of the software. Customers and engineers often speak of product criteria in terms of features that the product could deliver (Chen et al., 2005) and expanding on this.

Lee et al. (2000) stated that a feature is a prominent or distinctive aspect, quality or characteristic of a software system or systems. Thus, the feature analysis also includes identifying system features, constructing the feature model to organise the identified features in a consistent way, tracing the relationship between the features and implementing the system (Chen et al., 2005). It has been noted by studies (Chen et al., 2005; Lee et al., 2000) that features of the software can also be acquired from Request For Proposal (RFP), product demonstration, vendor investigation, document analysis, presentation, using trial versions as well as scheduling demonstrations or attending software trainings. All of these are actually strategies that can enhance the evaluation of the software products (Davis, 1989). In the e-LS evaluation, features are regarded as one of the selection criteria (Cavus & Ala'a, 2009). The evaluation criteria of a software may also be termed as factors, characteristics, attributes or features (McCall et al., 1977; Dromey, 1995; Cavus & Ala'a, 2009). In the context of this study, however, the term evaluation criteria will be used to represent the evaluation criteria of the e-LS.

2.4.4 Short listing of Software

The fourth stage is short listing the software packages. At this stage, the software packages are screened so as to reduce the large selection of software into a small number of software alternatives which makes it easier for evaluation (Kontio, 1996). The criteria related to vendor or software price can also be used to eliminate some of the alternatives software. A final list of available software packages that might be used as alternatives for the software evaluation can then be obtained (Jadhav & Sonar, 2009). Software packages that do not provide any essential functionalities and features or which do not work with the existing hardware, operating system, data management software or network should thus be eliminated (Jadhav & Sonar, 2009).

2.4.5 Evaluating of Software

The fifth stage is evaluating the software. The fit between the software products and the needs of that product is determined in the evaluation process through an appropriate technique (Punter et al., 1997). There are many evaluation techniques available such as Benchmark, Weight Score Method, Ranking and the AHP (Punter et al., 1997; Kunda & Brooks, 2000). These techniques can be used to rank and assign weight values to the criteria of the software products according to the evaluator's preferences (Hunt & Westfall, 2003; Kunda & Brooks, 2000). The aggregate score of each software is then calculated from the summation of the individual criteria scoring (Jadhav & Sonar, 2011). A general spreadsheet software can be used for the calculation and analysis.

2.4.6 Selecting of Software

The sixth stage is selecting the software. The aggregate scores acquired from the evaluation of the software would be ranked showing the software packages that are most relevant. This is indicative of their conformity to the evaluation criteria. The available software alternatives are then ranked in a list based on a descending order of the score. The final selection of the software is made based on the list generated.

2.4.7 Negotiating With Vendor

The seventh stage is negotiating with vendors. A preliminary research has to be performed so as to narrow down the list of vendors or suppliers that are available to the organizations so that only those most suitable can match the organization's needs. The software product's functionality and technical ability should also be provided by the vendors (Kunda & Brooks, 1999). Further to this, sufficient information should also be obtained from the vendor so as to be able to quantify each software product and its differences. This can be achieved via the formal Request For Proposal (RFP), supplier demos and conference, prototypes and evaluation copies as well as supplier evaluation, references and past performances (Nettleton, 2003; Hunt & Westfall 2003). Based on the comparison, the best software alternative is then chosen followed by the process of negotiating and signing a contract with the chosen vendor (Jadhav & Sonar, 2011). The negotiation stage includes an agreement made on the software price, the number of licenses attached, the payment schedule, functional specifications, repair and maintenance responsibilities, time table for delivery, and options for termination (Illa et al., 2000).

2.4.8 Purchasing of Software

The eighth stage is the purchasing of the software. When purchasing the software, the price/performance trade-off needs to be considered so as to identify the software which represents the best value for the organizations (Jadhav & Sonar, 2011). This allows the organizations to purchase the most appropriate software to be implemented in their organizations (Jadhav & Sonar, 2009).

The above discussion shows that the evaluation and selection process of software products consist of several activities. The evaluation and selection tasks are important because an improper selection of a software may result in wrong strategic decisions with economic losses to the organizations concerned (Jadhav & Sonar, 2009). This includes acquiring a software which exceeds the available budget, a bad product selection and the procurement of software products that do not fit the user's requirements.

2.5 Software Evaluation Model and the COTS Framework

There are two main approaches for the evaluation and selection process of a software. They encompass the Software Quality Model (SQM) and the COTS framework.

2.5.1 Software Quality Model (SQM)

The Software Quality Model (SQM) is based on artifacts and it is used for describing the quality factors of a single software product of any nature or a software domain (Botella et al., 2004). In describing the software domain, the examples of SQM are used in the Enterprise Resource Planning (ERP) system or the document management tools. Here, quality is defined as the set of features and characteristics that belong to a product or service; it is also based on the ability of the product or service to satisfy the stated or implied needs of the user (ISO/IEC9126-1, 2001). A quality model is thus defined as a set of characteristics and the relationship between those characteristics; this provides the basis for specifying the quality requirement and the evaluation of that quality (Behkamal et al., 2009). The SQM also provides a taxonomy of software quality criteria which can be used (Botella et al., 2004) in a number of contexts such as during the development of a new application or when selecting commercial components (Dromey, 1996; Franch & Carvallo, 2002; Botella et al., 2004). Some examples of the existing software quality model include Mc Call's Model, Boehm's Model, Dromey's Model and the ISO/IEC 9126-1 Quality Model (Samadhiya et al., 2010).

2.5.1.1 McCall's Model

McCall's Model was developed in 1977 by the US air-force electronic system division together with the Rome air development center (RADC) and General Electric (GE) (Ravichandran & Rothenberger, 2003). This model was developed with the purpose of improving the quality of software products (McCall et al., 1977). McCall's Model allows the relationship between the quality criteria and the metrics to be seen (AL-Badareen et al., 2011). Initially, the model had provided 23 quality criteria which described the developer's view of the software and the metrics which are defined and used to provide a scale in the method for measurement. McCall's Model for software quality combines eleven criteria together. These are then categorized into three perspectives: product revision, product transition and product operation (McCall et al., 1977; Fitzpatrick, 1996).

a. Product revision: The product revision perspective identifies the quality criteria which influence the ability to change the software product. It is related to error correction and system adaptation. This perspective is important because it is generally, the costliest part of software development (Ortega et al., 2003). The criteria of product revision include:

i. *Maintainability*: the ability to find and fix a defect.

ii. *Flexibility*: the ability to make changes required as dictated by the business.

iii. *Testability*: the ability to validate the software requirements.

b. Product transition: The product transition perspective identifies the quality criteria which influence the ability of the software to adapt to new environments. This perspective may not be important for all applications but the current trend towards distributed processing, together with rapidly changing hardware, is likely to increase its importance (Ortega et al., 2003). The criteria of product transition include:

i. *Portability*: the ability to transfer the software from one environment to another.

ii. *Reusability*: the ease of using the existing software components in a different context.

iii. *Interoperability*: the extent, or ease, to which software components work together.

c. Products operation: The products operation perspective identifies the quality criteria that influence the extent to which the software fulfils its specifications. This perspective also refers to the product's ability to be quickly understood, efficiently operated and capable of providing the results required by the user (Ortega et al., 2003). The criteria of products operation include:

i. *Correctness*: the functionality matches the specification.

ii. *Reliability*: the extent to which the system fails.

iv. *Efficiency*: the system resource which include the CPU, disk, memory and network usage.

iv. *Integrity*: protection from unauthorized access.

v. *Usability*: ease of use.

In McCall's Model (Mc Call et al., 1977) as shown in Figure 2.3, the criteria on the left hand side represent an aspect of quality that is not directly measurable. On the right hand side is an aspect of quality that is measurable and can be evaluated in order to quantify the quality in terms of the criteria.

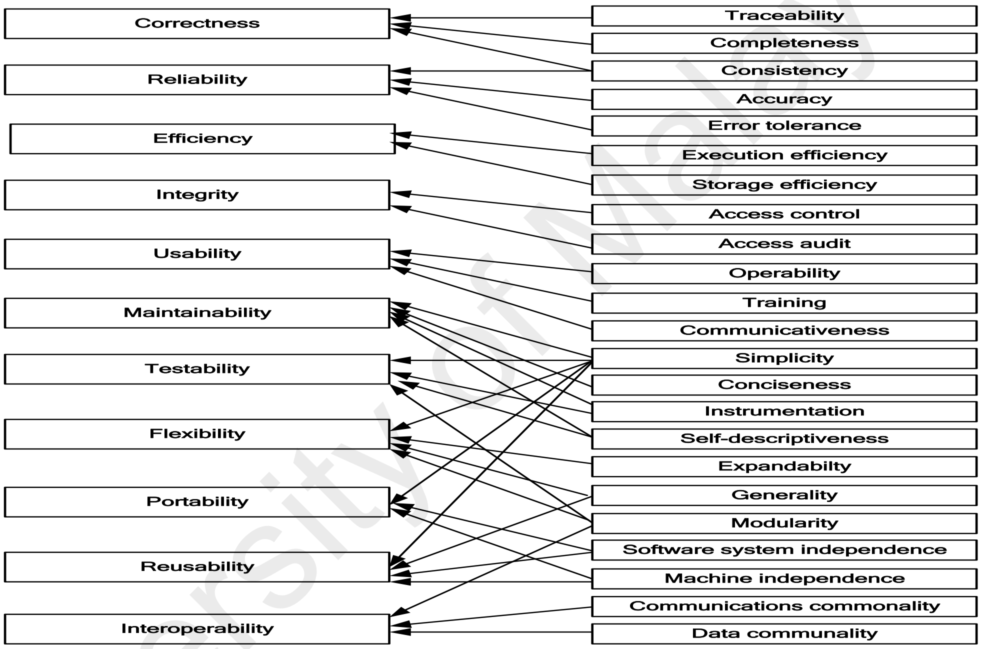


Figure 2.3: McCall's Model (McCall et al., 1977)

The weakness of McCall's Model is that it does not consider the functionality of the software products directly (AL-Badareen et al., 2011). It is difficult to be used to set a precise and specific quality requirement since all the criteria are measured subjectively (Pressman, 2001). One of the major contributions of McCall's Model is the determination of the relationship between the quality criteria and their metrics but criticisms note that that not all the metrics are objective. Another important criticism is that this mode does not consider the functionality of the software products directly (Behkamal et al., 2009).

2.5.1.2 Boehm's Model

Boehm's Model was derived from the improvement made to McCall's Model (Boehm et al., 1978) where several criteria that emphasize the maintainability of the software products were added (Botella et al., 2004). Boehm's Model incorporates criteria which are related to the hardware's performance, an aspect that was not included in McCall's Model. Boehm's Model takes into consideration the utility aspect from various dimensions by looking at the types of users that were expected to be working in the system. Boehm's Model defines three primary uses (or basic software requirements), which are further broken down into primitive constructs that can be measured (Samadhiya et al., 2010). Boehm's Model is presented in Figure 2.4.

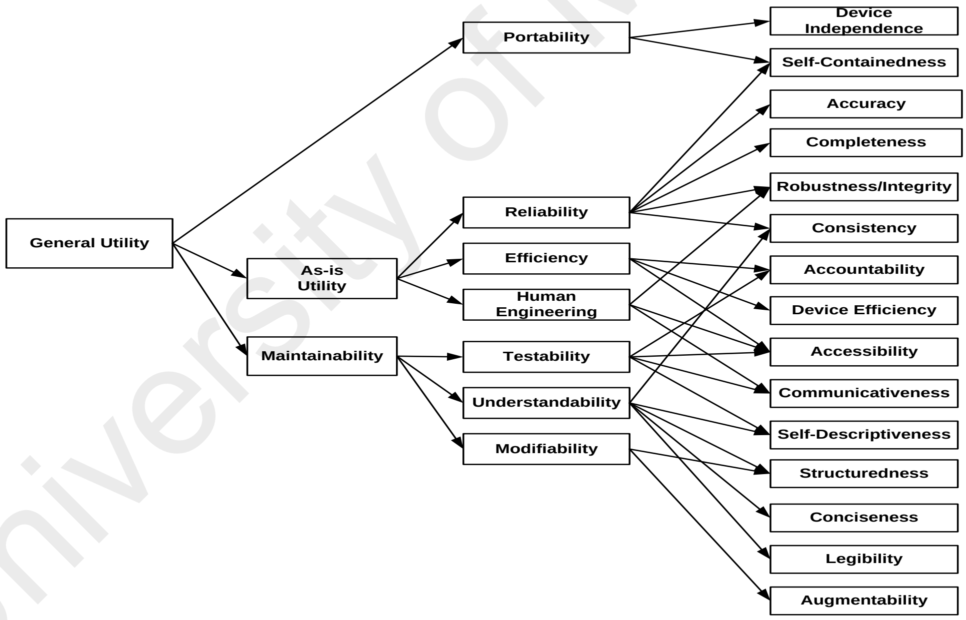


Figure 2.4: Boehm's Model (Deifel, 1998)

The weakness of Boehm's Model is that this model is only based on a diagram; it does not offer any suggestion on how the measurement of the quality criteria is processed (AL-Badareen et al., 2011).

2.5.1.3 ISO/IEC 9126-1 Quality Model

The ISO/IEC 9126-1 (International Standard for Organization International/Electrotechnical Commission 9126-1) Quality Model is a set of international standard which is used to evaluate the quality of a software product. The ISO/IEC 9126-1 Quality Model embraces both the quality models of McCall and Boehm and the metrics determination. It is also one of the most widespread quality standards that is available in the world (Botella et al., 2004). The ISO/IEC 9126-1 Quality Model was developed based on the McCall's Model and Boehm's Model (Samadhiya, et al., 2010). The quality model is defined by means of the general criteria of software which is subsequently further refined into sub-criteria, which in turn, are decomposed into specific criteria and sub-criteria, yielding to a multilevel hierarchy (Botella et al., 2004). The ISO/IEC 9126-1 Quality Model can identify software quality criteria such as *Functionality, Maintainability, Usability, Reliability, Portability* and *Efficiency*. Table 2.1 shows the criteria and the sub-criteria of the ISO/IEC 9126-1 Quality Model.

The criteria definitions of the ISO/IEC 9126-1 Quality Model include:

i. *Functionality*: The capability of the software system to provide functions that meet stated needs and when the system is used under specified conditions.

ii. *Reliability*: The capability of the software system to maintain its level of performance under certain conditions for a stated period of time.

iii. Usability: The capability of the software system to be understood, learned and be attractive to the user when used for specified conditions.

iv. Efficiency: The capability of the software system to provide appropriate performance relative to the amount of resources used under stated conditions.

v. *Maintainability*: The capability of the software products to be modified. Modifications may include corrections, improvements or adoptions of the system to change in environment and in the requirements and functional specifications.

vi. *Portability*: The capability of the software products to be transferred from one environment to another.

Table 2.1: The Evaluation Criteria and Sub-criteria of the ISO/IEC 9126-1 Quality Model.

Criteria	**Sub-criteria**
Functionality	*Suitability*
	Accurateness
	Interoperability
	Compliance
	Security
Reliability	*Maturity*
	Fault Tolerance
	Recoverability
Usability	*Understandability*
	Learnability
	Operability
Efficiency	*Time Behavior*
	Resource Behavior
	Analyzability
Maintainability	*Changeability*
	Stability
	Testability
	Adaptability
Portability	*Installability*
	Conformance
	Replaceability

A study using the ISO/IEC 9126-1 Quality Model as a framework can be traced to the evaluation of an e-Book in the education system (Fahmy et al., 2012). One weakness of the ISO/IEC 9126-1 Quality Model is that it is only a general model for software evaluation and selection. In order to apply this model for the evaluation of a particular e-LS, organizations may have to adjust and customize it accordingly for it to become appropriate for the evaluation of a particular domain application (Behkamal et al., 2009).

2.5.1.4 Dromey's Model

Dromey (1995) proposed a model which consists of eight high level quality criteria. The model attempts to highlight the relationship between the criteria and the sub-criteria of quality (Dromey, 1995). To accomplish this, Dromey (1995) acknowledged the use of a list of desirable but high level criteria (Dromey, 1995; Dromey, 1996). Dromey's model states that the software quality criteria must be considered in a systematic and structured way and it distinguishes the tangible from the intangible as is illustrated in Figure 2.5.

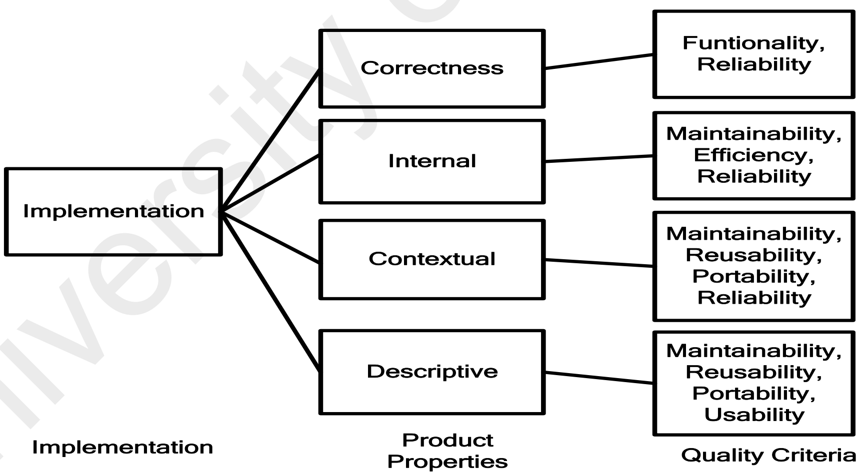


Figure 2.5: Dromey's Model

Dromey's Model also explained what is meant by software components (Côté et al., 2007) and they are further defined below:

i. Variables, functions and statements can be considered as components of the implementation model;

ii. A requirement can be considered a component of the requirements model;

iii. A module can be considered a component of the designed model;

According to Dromey (1995), all these components possess intrinsic properties that can be classified into:

i. Correctness: Evaluates if some basic principles are violated. The criteria from correctness are *Functionality* and *Reliability*.

ii. Internal: Measures how well a component has been deployed according to its intended use. The criteria of the internal product properties are *Maintainability*, *Efficiency* and *Reliability*.

iii. Contextual: Deals with the external influences by and on the use of a component. The criteria from the contextual properties are *Maintainability*, *Reusability*, *Portability* and *Reliability*.

iv. Descriptive: Measures the descriptiveness of a component. The criteria of the descriptive product properties are *Maintainability*, *Reusability*, *Portability* and *Reliability*.

According to Côté et al. (2006), Dromey's Model is interesting from a technically inclined stakeholder's perspective. However, it is difficult to see the applicability of the model at the beginning of the lifecycle which can determine users' quality needs.

2.5.1.5 ISO/IEC 25010

The ISO/IEC 25010 was developed based on the ISO/IEC 9126-1 Quality Model (Sheoran & Sangwan, 2015). The goal of this model was to provide guidance to users in developing the software products that come with the evaluation and specification of the requirements of quality (ISO/IEC 25010, 2011). This model describes the software product quality model and the software quality in use.

a. Product Quality Model

The product quality model is composed of eight criteria which are subdivided into sub-criteria that relate to the static properties of software and the dynamic properties of the computer system (ISO/IEC 25010, 2011). The product quality model describes the internal and external measures of the software quality. The Internal measures describe a set of static internal attributes which can be measured whereas the external measures focus more on the software as a black box and so it describes the external attributes of the software (Bánsághi et al., 2012). The model is applicable to both the computer system and the software products (ISO/IEC 25010, 2011). It is illustrated in Figure 2.6.

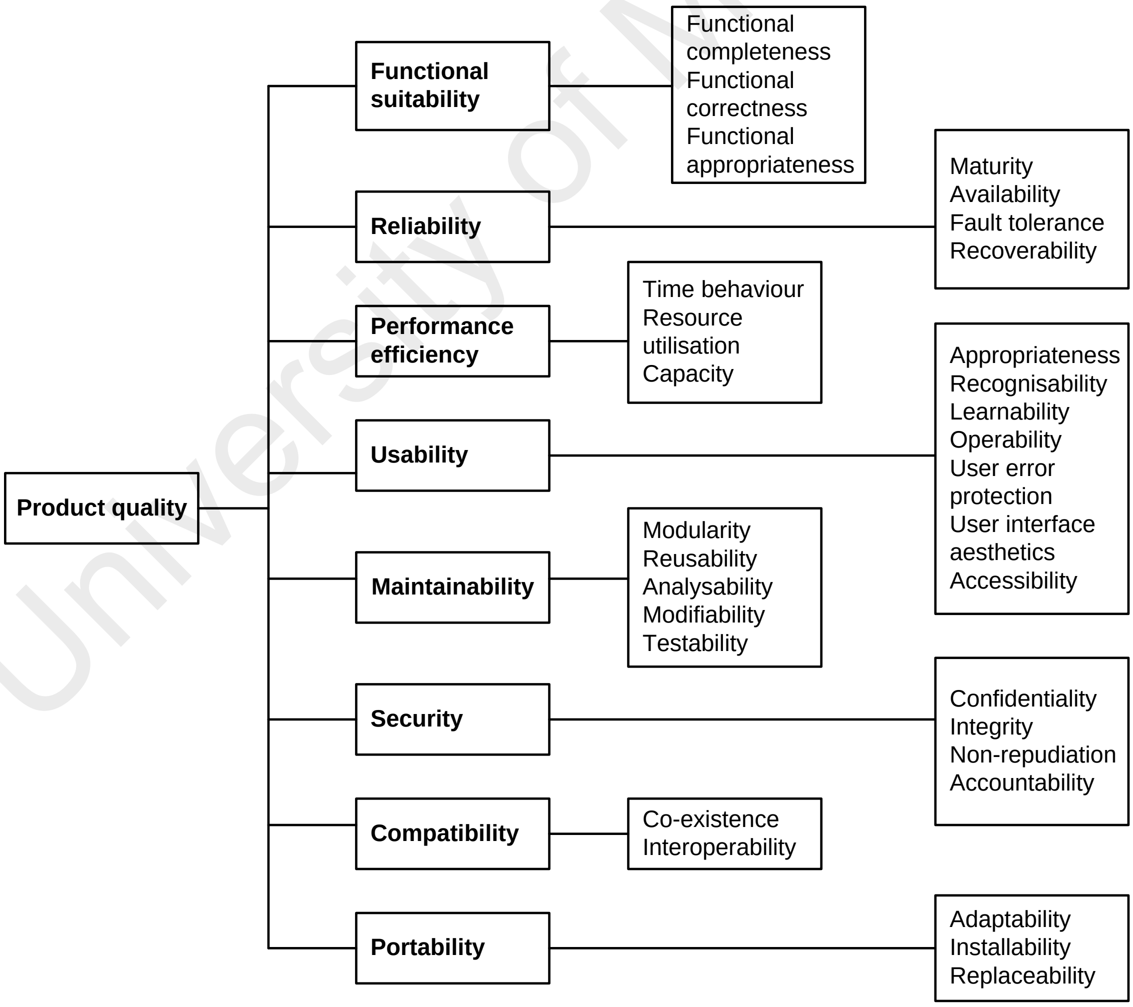


Figure 2.6: Product Quality Model of ISO/IEC 25010

b. Quality in Use Model

The quality in use model is composed of five criteria which are subdivided into sub-criteria that relate to the outcome of the interaction when a product is used in a particular context (ISO/IEC 25010, 2011). This model is applicable for the human-computer system including computer system in use and software products in use. This model is reflected in Figure 2.7.

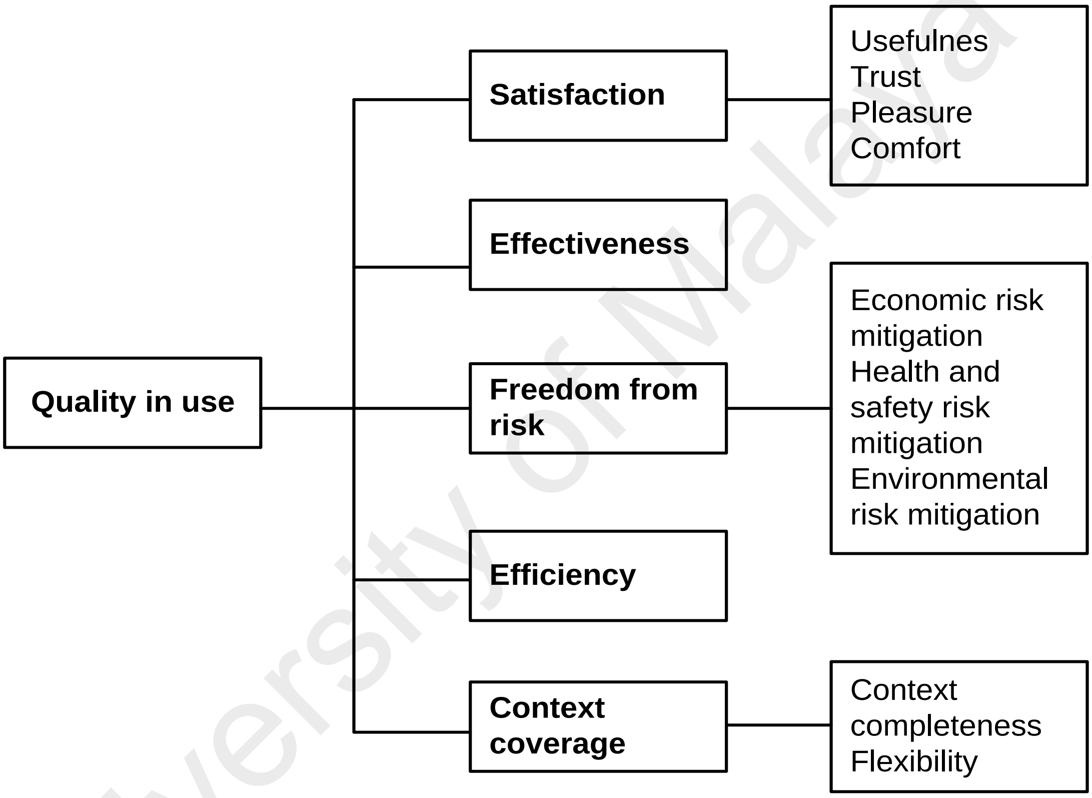


Figure 2.7: Quality in Use Model of ISO/IEC 25010

The criteria defined by the product quality and quality in use models are relevant to all the software products and computer systems. The criteria and sub-criteria also provide a consistent terminology for specifying, measuring and evaluating the system and software product quality. They also serve as a set of quality criteria against which the stated quality requirements can be compared to for completeness (ISO/IEC 25010, 2011).

2.5.2 COTS Evaluation Framework

The introduction of the COTS software has been presented in Section 1.1. The COTS software is obtained so as to reduce the investment cost of any particular Information System (IS) acquired by an organization (Lin et al., 2007; Mansoor et al., 2007). The COTS evaluation framework is an alternative software development approach; it is based on the integration of pre-packaged solutions usually known as COTS software. Ruhe (2003) formulated a process approach which was in the form of a general COTS evaluation process but it includes six stages of evaluation and selection process as presented below:

i. Define the evaluation criteria based on stakeholders' requirements and constraints.

ii. Search for COTS products.

iii. Filter the search results based on a set of requirements.

iv. Evaluate COTS alternatives on the short list.

   COTS are evaluated against a set of criteria that represents the stakeholders' requirements and system constraints (Tate, 2003). Evaluation techniques such as AHP can be used in the evaluation process (Zaharias et al., 2002).

v. Analyse the evaluation data; and

vi. Select the COTS product that has the best fit with the criteria. The selected COTS product is usually customized as required in order to reduce the mismatches it may still have with the requirements.

In the COTS evaluation framework, the six stages can serve as a general guideline for organizations to follow. As an evaluation guide, the COTS framework consists of both an input and an output process which allow the organization to capture its "know how" on performing the evaluations (Comella-Dorda et al., 2002). The COTS framework describes how an evaluation is performed and it includes descriptions of the processes and techniques involved. Each COTS product evaluation adds to the organization's knowledge about evaluation but this new information may not have been recorded in the evaluation guide. Nonetheless, these processes are applied or customized by organizations when constructing the evaluation framework for COTS software. Examples of the COTS based framework for COTS evaluation process include Off-The-Shelf-Option (OTSO), Procurement-Oriented Requirements Engineering (PORE), COTS Acquisition Process (CAP) and The Social-Technical Approach to COTS Evaluation (STACE).

2.5.2.1 Off-The-Shelf-Option (OTSO)

The OTSO provides a decision framework that supports multivariable software component selection analysis (Feblowitz & Greenspan, 1998) for the selection of COTS and other OTS (Off-The-Shelf) software components (Kontio, 1996). The OTSO addresses the complexity of the software component selection (Kontio, 1996). It facilitates a systematic, repeatable and requirement-driven framework for the COTS selection process (Kontio, 1996). The following are the main principles of the OTSO method as stated by Kontio, (1996):

i. Explicit definition of tasks in the selection process including the entry and exit criteria;

ii. Incremental, hierarchical and detailed definition of the evaluation criteria;

iii. A model for comparing the cost and value that is associated with each alternative, making them comparable with each other;

iv. The use of appropriate decision making methods to analyze and summarize the evaluation results.

The OTSO process defines the evaluation criteria, compares the costs and benefits of the alternatives and consolidates the evaluation results by using the AHP technique for decision-making (Tate, 2003). The process in the OTSO involves:

i. search phase;
ii. screening phase;
iii. evaluation phase; and
iv. analysis phase.

In the search phase, the alternatives of COTS software components are identified. At this phase, the requirements are not fully specified. The requirements for the COTS are decomposed into a hierarchical criteria set. Each branch in this hierarchy ends in an evaluation attribute: a well-defined measurement or piece of information that is determined during the evaluation. the OTSO compares the COTS software components based on value and cost. The value is estimated based on the hierarchical evaluation criteria which consist of functionalities, qualities, strategic concerns, and architectural constraints. The evaluation criteria are influenced by five factors:

i. application requirements;
ii. architecture;
iii. project constraints,
iv. availability of required features, and
v. organization infrastructure, for example, level of experience.

In the screening phase, the alternatives are screened and reduced to a number of COTS software component options. Following that, a decision is made on which alternatives to be selected for a more detailed evaluation. The evaluation process is then conducted to evaluate the selected alternatives based on the results of the evaluation criteria.

The search and screening phases enable the understanding of the software component capabilities which provide feedback to the requirements' definition process. This can result in a refinement or modification of the known requirements as well as the introduction of some new requirements.

In the evaluation and analysis phase, the selection process is based on the analysis of the results of the evaluation. The analysis of the results rely on the use of the AHP technique for consolidating the evaluation data to assist decision-making purposes (Cechich et al., 2002). This then leads to the final selection of the COTS software component.

In most cases, the evaluations are always performed against a set of evaluation criteria which have been established based on a number of sources including the requirements' specification and the high-level design specification of the project plan (Dean et al., 2000). The OTSO process, as shown in Figure 2.8, is iterative because the requirements are both refined and defined throughout the evaluation process.

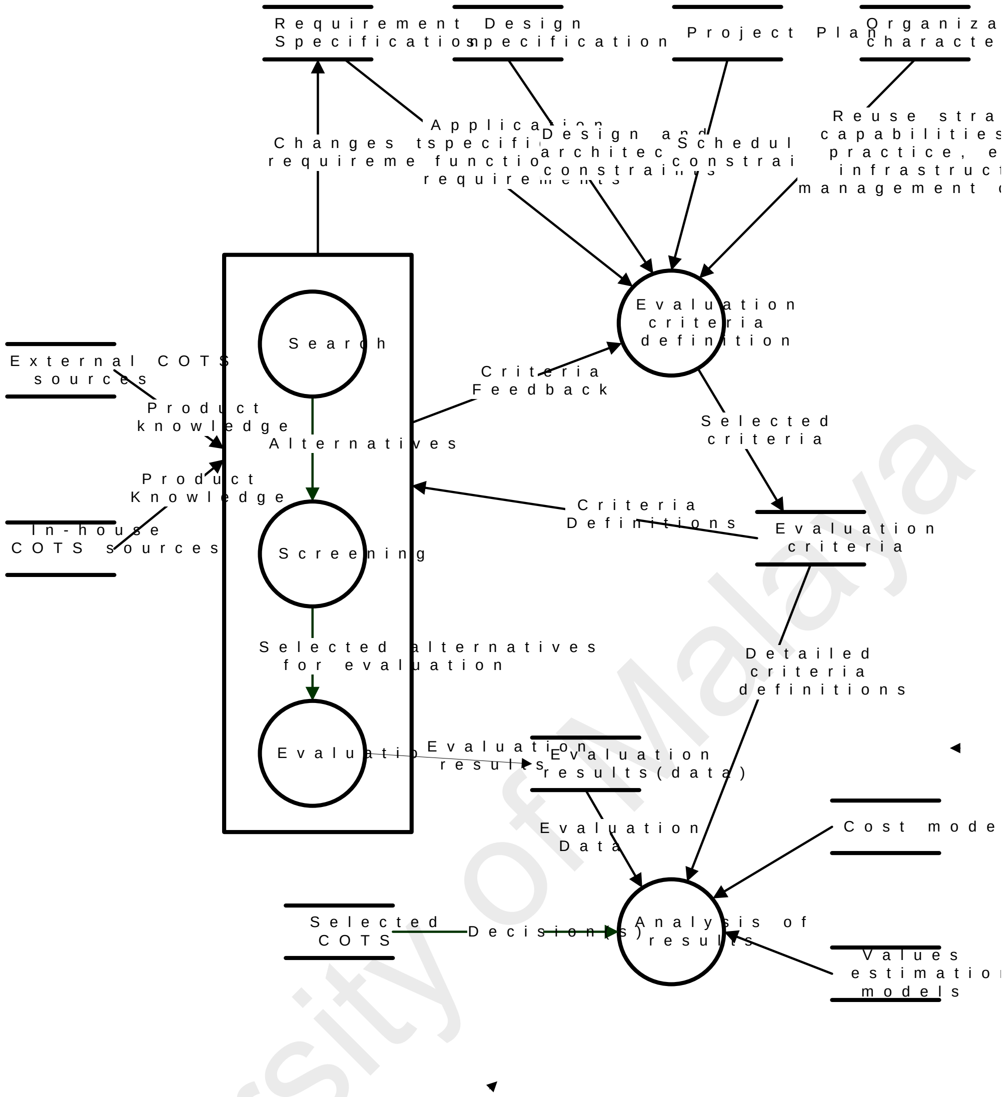


Figure 2.8: The Process in OTSO (Kontio, 1996)

However, the weakness of the OTSO is that the criteria definition must be revisited for each project because each of the criteria would evolve at different times (Kontio, 1996).

2.5.2.2 Procurement-Oriented Requirements Engineering (PORE)

The PORE framework is based on an iterative process which focuses on the requirements engineering phase of the COTS procurement process (Maiden & Ncube, 1998). The PORE framework suggests iterating between requirements' acquisition and product selection and rejection until a COTS software product is found to satisfy a sufficient number of the requirements (Tate, 2003). There are three main components in the PORE (Ncube & Maiden, 1999) framework:

i. A process model that identifies four essential goals that should be achieved by any COTS based process. Generic processes are prescribed for the accomplishment of each of these goals and the sequence in which these goals should be achieved;

ii. A method box that includes methods, techniques and tools that are available in assisting to undertake and achieve each of the processes;

iii. A product model that provides semantics and syntax for modeling software products.

The PORE framework also suggests that the requirements be defined for evaluating COTS software. PORE also encourages a requirements engineering team to acquire, describe and analyze customer requirements at the same time as acquiring, modeling and analyzing alternative COTS software products.

The three sample templates noted in PORE provide a preliminary view of some of the steps needed to perform a justifiable evaluation of the alternative COTS software product (Ncube & Maiden, 1999) as informed below:

i. To guide the requirements engineer when acquiring essential customer requirements and sufficient product information to select and reject products as a result of supplier-given information.

ii. To guide the requirements engineer when acquiring customer requirements and sufficient product information to select and reject products from supplier-led demonstrations using test-cases for individual requirements;

iii. To guide the requirements engineer to acquire customer requirements and sufficient product information to select and reject products as a result of customer-led product exploration.

PORE supports iterative requirements acquisition and product selection until one or more products are compliant with a sufficient number of customer requirements. PORE consists of four generic processes which can be used to achieve the goals, as shown in Figure 2.7.

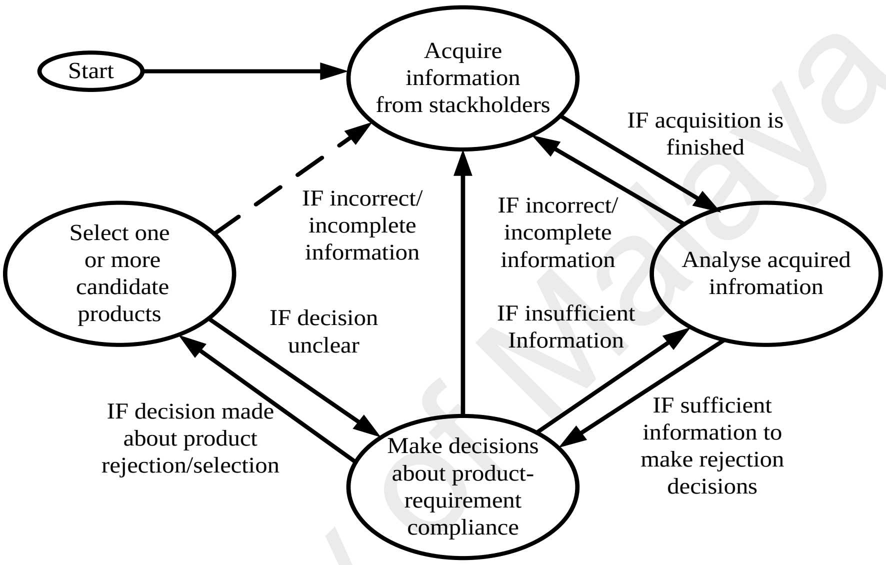


Figure 2.9: Four Generic Processes in PORE (Ncube & Maiden, 1999)

PORE provides four processes which are as follows:

i. Acquire information from stakeholders;
ii. Analyze acquired information for completeness and correctness;
iii. Use this information to make decisions about product-requirement compliance; and
iv. Reject one or more alternative of COTS software products as non-compliant with customer requirement.

The processes described, however, is one in which requirements are defined in line with COTS component evaluation and selection. PORE utilizes the AHP technique for evaluation (Kitchenham et al., 1997).

The weakness of PORE, however, is that the selection process needs to proactively evaluate the actual product and not rely exclusively on the vendor-supplied documentation or demonstration (Ncube & Maiden, 1999). PORE is not clear in its ability to specify the requirements and to eliminate products. For instance, it does not capture the decision rationale. Moreover, PORE also depends on templates to acquire and evaluate alternatives of COTS software products even though these templates only provide the initial view of the steps in conducting a systematic evaluation (Tarawneh et al., 2011).

2.5.2.3 Social-Technical to COTS Evaluation (STACE)

The STACE framework was developed through literature review and based on empirical studies. It emphasizes on the importance of non-technical issues when defining the evaluation criteria and when conducting the evaluation process (Sommerville, 1996). The STACE framework consists of four interrelated process as illustrated in Figure 2.8.

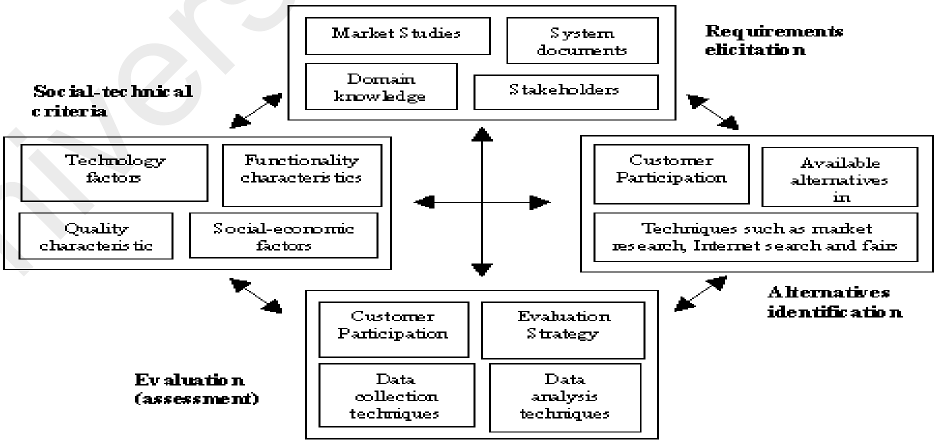


Figure 2.10: STACE Framework (Kunda & Brooks, 1999)

The four interrelated processes are:

a. Requirements' Elicitation

In this process, the high-level customer and systems requirements are identified through consultations with stakeholders. This is achieved through the system documents, domain knowledge and market studies (Kunda & Brooks, 1999).

b. The Social-Technical Criteria

In the Social-Technical Criteria process, the social-technical criteria are defined and they include technology, functionality, product quality criteria and other social-economic criteria (Kunda & Brooks, 1999).

c. Alternative Identification

The Alternative Identification process includes searching and screening for COTS software products which will be assessed in the evaluation stage. This process is driven by the guidelines and criteria defined in the criteria definition process.

d. Evaluation Process

The Evaluation process involves ranking the identified COTS software alternatives against the social-technical evaluation criteria. This is accomplished by examining the capabilities, reading documentations and experimentations. Figure 2.9 shows the steps involved in the evaluation process of STACE.

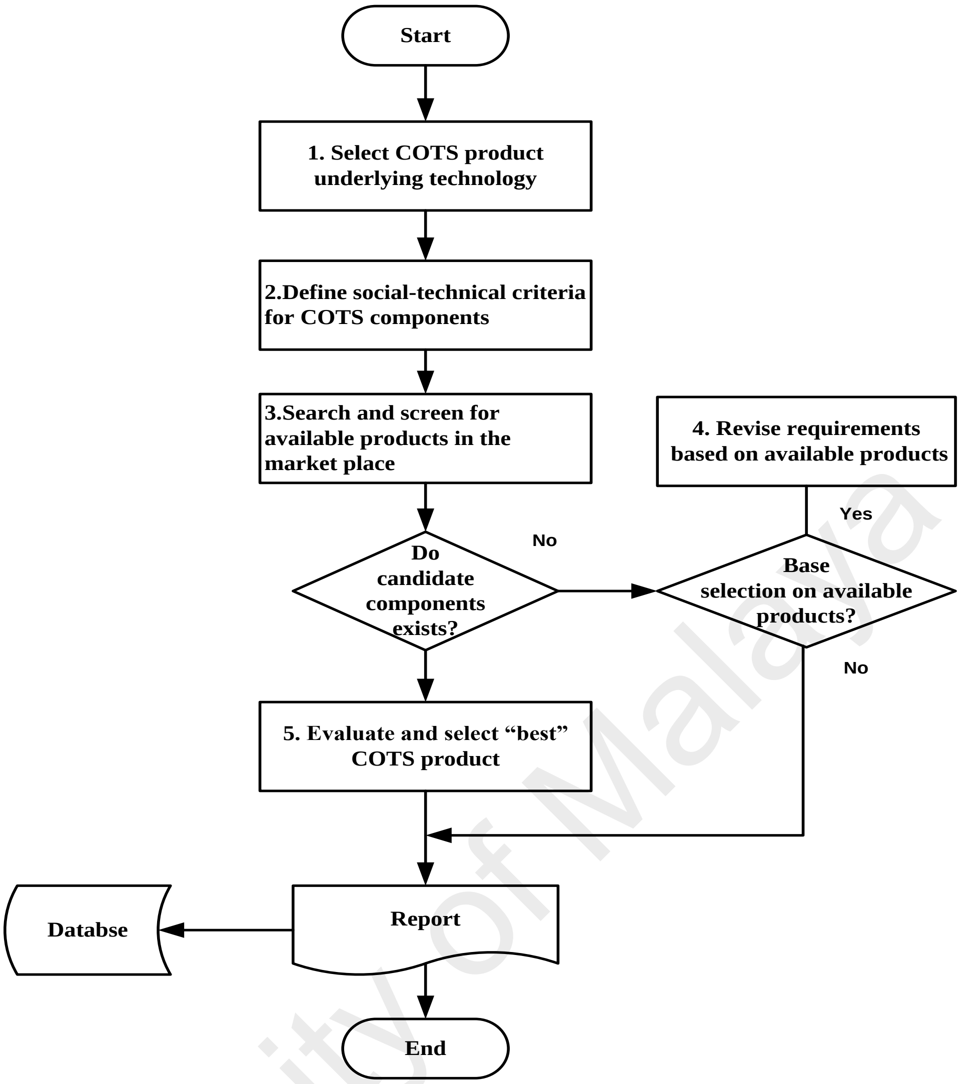


Figure 2.11: STACE Evaluation Process (Kunda, 2001)

The STACE evaluation process as shown above addresses both the technical and the social aspects of the evaluation. It uses the AHP technique for making complex multi-attribute decisions. The STACE framework ensures that all the relevant factors for COTS software selection are covered in the criteria on which the AHP would rate the different alternatives (Kunda, 2001).

The main weakness of STACE is the lack of a process of requirements acquisition and specification. This approach does not provide or use a systematic analysis of COTS alternatives during the assessment or when using a decision-making technique (Taraweh et al., 2011).

2.5.2.4 COTS Acquisition Process (CAP)

The acquisition process of COTS, hereby also termed as CAP, emphasizes the concept of a tailorable evaluation process (Och et al., 2000). It also consists of three process components namely:

a. CAP Initialization Component (CAP-IC)

The CAP-IC comprises all activities that are related to the definition of the decision basis and the measurement plan. It also deals with the planning of the evaluation process and cost estimation which encompass:

- Tailor and weight taxonomy of the evaluation criteria
- Estimating the cost of applying CAP
- Elaborating on the measurement plan

b. CAP Execution Component (CAP-EC)

The CAP-EC comprises all activities that deal with the identification of possible COTS software alternatives. It also performs the measurement and decision-making on the set of available COTS software alternatives. The CAP-EC provides guidance for users to conduct the evaluation process which includes:

- Exploring COTS products
- Collecting measures, where the COTS software are initially evaluated
- Screening, where the products with less compliance with the criteria are filtered out
- Collecting measures, where the COTS software are evaluated more extensively
- Ranking of COTS using AHP
- Make-or-Buy, where the highest r anked COTS software is selected if it passes a make-or-buy decision.

c. CAP Reuse Component (CAP-RC)

The CAP-RC comprises all activities which refer to the packaging information of the COTS software for reuse in the future CAP enactment. In CAP, the evaluation process which covers the evaluation criteria should be tailored based on the available effort for the project (Och et al., 2000). CAP is a measurement oriented approach which ensures that the evaluation process is tailored according to the estimation of the measurement effort. This is called the evaluation taxonomy. This Evaluation Taxonomy is part of the measurement and decision-making procedure within the CAP component (Och et al., 2000). CAP also introduces a reusable taxonomy for the evaluation criteria. The evaluation taxonomy of CAP is organized in a four-level tree, as shown in Figure 2.10.

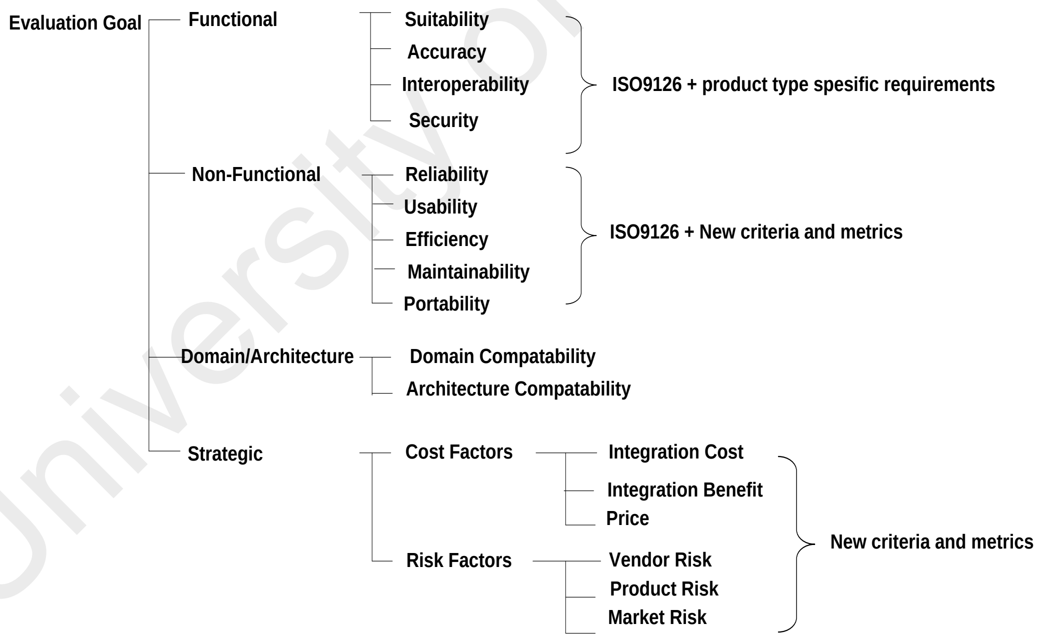


Figure 2.12: The Taxonomy of CAP (Och et al., 2000)

Like all the other models, there are also some weaknesses contained in CAP such as the assumption that the requirements are already in existence and fixed. CAP also assumes that there is a set of COTS software which satisfy most of the requirements, at least to an acceptable level. Therefore, the users of CAP would only use the available requirements provided in the approaches. Undoubtedly, CAP has inherited the weaknesses of the AHP or WSM, such as consolidating the results into a single score which can be misleading to users (Mohamed et al., 2007).

2.6 Software Evaluation Technique

A suitable software evaluation technique, as introduced in Section 2.4.1.5, can be used to evaluate software products. Further elaborations on these techniques are described in the following section.

2.6.1 Benchmark Technique

The Benchmark technique is the process of running a number of standard test/trials using a number of alternative tools. This benchmark technique is used to access the relative performance of the tools in those tests (Kitchenham & Pfleeger, 1996). Romney et al. (2012) has suggested using the benchmark technique to measure the processing times of the software, where the lowest processing time would be chosen as the judging criteria for being the most efficient software. The Benchmark technique has been traditionally used to compare the performance of computer systems, information retrieval algorithms, databases, and many other technologies (Sim et al., 2003).

2.6.2 Multi Criteria Decision Making Technique (MCDM)

Software evaluation is considered a MCDM problem whereby the decision is made in the presence of multiple criteria and alternatives (Köksalan et al., 2011). The MCDM problem usually involves the evaluation of a set of attributes, decision criteria and alternatives (Colombo & Francalanci, 2004). To overcome the problem, the MCDM technique can be used to describe the processes which consist of steps used to evaluate the software. It can also be used as the evaluation technique when evaluating the MCDM techniques such as Weight Score Method, Ranking and AHP, all of which, have been used in many software selections (Zahedi, 1985; Dewal et al., 1992; Kontio, 1996; Lai et al., 1999; Sarkis & Talluri, 2004; Wei et al., 2005; Mohamed et al., 2007). Examples of the MCDM techniques used in software selection include:

i. Weight Score Method (WSM) (Chen et al., 2005);

ii. Analytical Hierarchy Process (AHP) (Kontio, 1996); and

iii. Fuzzy Analytical Hierarchy Process (Fuzzy AHP).

2.6.2.1 Weight Score Method (WSM)

The Weight Score Method or WSM is a method that is also applicable for evaluating a software package (Chung & Cooper, 2001; Deifel, 1998). The application of the WSM is straightforward whereby the criteria are defined and then assigned a weight score (Kontio, 1996). According to Jadhav & Sonar (2009), the weights and rating scales are assigned to each criterion so as to reflect the relative importance of each of the criteria and how easily each software is able to meet the specific criterion, respectively (Jadhav & Sonar, 2009). The rating scales are then multiplied by the weight of each criterion and the score is calculated for every criterion of each software. These scores are totalled to produce a score for each criteria category. The categorical scores are then combined to calculate an overall tool score (Jadhav & Sonar, 2009).

The WSM offers the following benefits (Jadhav & Sonar, 2009):

i. The WSM is easy to use

ii. The WSM is easy to understand

Limitations of the WSM include:

i. Weights are assigned arbitrarily to the attribute and it can become difficult to assign if the number of criteria is high.

ii. A common numerical scaling is required to obtain a score (Jadhav & Sonar, 2009).

iii. Difficulties will occur when it is applied to a set of multi criteria MCDM problems (Jadhav & Sonar, 2009).

iv. Difficulty in mentally coping with the dependencies of the individual factors of the decision maker when applied in the software assessment for a set of large criteria (Kontio, 1996).

The application of the WSM in past studies is shown in Table 2.2.

Table 2.2: The Application of the WSM in Software Selection

Authors	**The application**
Maiden & Ncube (1998)	Acquiring COTS Software Selection Requirements
Kontio (1996)	A Case Study in applying a Systematic Method for COTS selection
Jadhav & Sonar (2011)	Model for evaluation and selection of the software packages: A hybrid knowledge based system approach

2.6.2.2 Analytical Hierarchy Process (AHP) Technique

The Analytical Hierarchy Process or AHP technique was developed by Saaty (1980). It is one of the best methods for making decisions when faced with a set of complex criteria structure at the different levels of evaluation (Karimi et al., 2011). According to Karimi et al. (2011), the AHP technique is suitable for dealing with complex systems that are related to several alternatives. It provides a comparison of the considered options thus the AHP technique can help in organizing the critical aspects of a problem by placing them into a hierarchical structure that is similar to a family tree (Zahedi, 1985). The structure of the hierarchy depends on the nature or type of managerial decisions. The number of levels in a hierarchy depends on the complexity of the problem being analyzed (Zahedi, 1985).

Badri (1999) emphasized that the AHP technique enables the decision maker to structure a complex problem into a simple hierarchy so that a large number of quantitative and qualitative factors can be analyzed in a systematic manner with conflicting multiple criteria. By reducing the complex decisions to a series of pairwise comparisons and rankings, a synthesized result can be accomplished. The AHP technique not only helps decision makers to make best decisions but also a clear rationale for the choices made (Saaty, 1980; Karimi et al., 2011). The AHP technique involves four major steps (Cheng et al., 1999) namely:

Step 1: Breaking down the complex problem into a number of small constituent elements and then structuring the elements in a hierarchical form.

In this step, the problem of selection is defined by structuring the decision into a hierarchy. The overall goal of the decision is represented at the top level of the hierarchy. The criteria and sub-criteria contributing to the decision are represented at the intermediate levels. The decision alternatives are placed at the bottom level of the hierarchy.

Step 2: Making a series of pairwise comparisons among the elements according to a ratio scale

The AHP technique relies on pairwise comparison and the use of crisp or exact numbers as the criteria weights. In pairwise comparison, each element in an upper level is used to compare the element in the level immediately below it. The next step is to determine the priorities of the elements at each level. To prioritize and convert the individual comparative judgments into a relative scale measurement, a set of comparison matrices of all the elements that are in each level of the hierarchy, with respect to the element that is on the immediate higher level, are constructed.

The pairwise comparisons are given in terms of how much element A is more important than element B. According to Cheng and Li (2001), the AHP technique is a subjective approach. The information and the priority weights of the elements may be obtained from the decision-maker of the organization by using direct questioning or by the survey/questionnaire method (Cheng & Li, 2001). The 9-point scale developed by Saaty (1980) allows the respondents to express their preferences between options as equally important, moderately important, strongly important, very strongly important, or extremely important. The 9-point scale used for the pair wise comparison (Armacost et al., 1994) is shown in Table 2.3.

Table 2.3: Saaty's Scale for Pairwise Comparison Using Original Crisp Value

Saaty's Scale	The relative importance of the two sub-elements
1	Equally important
3	Moderately important with one over another
5	Strongly important
7	Very Strongly important
9	Extremely important
2,4,6,8	Intermediate values

These comparisons are used to obtain the weights of the importance of the decision criteria and the relative performance measures of the alternatives, in terms of the individual decision criterion (Triantaphyllou & Mann, 1995). If the comparisons are not perfectly consistent, it then provides a mechanism for improving the consistency (Triantaphyllou & Mann, 1995).

Step 3: Using the eigenvalue method to estimate the relative weights of the elements

The pairwise comparisons generate a matrix of relative rankings for each level of the hierarchy. The number of matrices depends on the number of elements at each level. The order of the matrix at each level depends on the number of elements at the lower level that it is linked to.

Once all the matrices are developed and all the pairwise comparisons are obtained, the eigenvectors or the relative weights (the degree of relative importance amongst the elements), global weights and the maximum eigenvalue for each matrix are calculated.

The eigenvalue is an important validating parameter in the AHP technique. It is used as a reference index to screen information by calculating the Consistency Ratio (CR) (Saaty, 2000). The CR of each matrix would be analyzed to verify the level of logical inconsistency of the matrix. The Consistency Index (CI) can then be calculated accordingly.

The Random Index (RI) is a known random CI which is obtained from a large number of simulation runs and it varies depending on the order of the matrix. Table 2.4 shows the value of the RI for matrices of order 1 to 15 which is obtained by approximating the random indices using a sample size of 1000.

Table 2.4: Average Random Index (RI) Based on Matrix Size (Liu & Xu, 1987)

Size of matrix (n)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Random Index (R.I)	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.53	1.55	1.56	1.59

The Consistency Ratio is calculated through the following steps:

1. Compute the Consistency Index for each matrix of order *n* by using the formula:

   Consistency Index (CI)= (λmax-n)/ (n-1)

2. The Consistency Ratio is then calculated by using the formula:

   Consistency Ratio (CR) = Consistency Index (CI)/Random Index(RI)

The acceptable CR range may vary according to the size of the matrix i.e. 0.05 for a 3 by 3 matrix, 0.08 for a 4 by 4 matrix and 0.1 for all larger matrices, $n \geq 5$ (Saaty, 2000).

If the value of the $CR \leq$ *the acceptable value*, it implies that the evaluation within the matrix is acceptable and it indicates a good level of consistency in the comparative judgment that is represented in that matrix. In contrast, if the $CR >$ *the acceptable value*, then inconsistency of the judgment of that matrix has occurred and the evaluation process should therefore, be reviewed, reconsidered and improved (Saaty, 2000). The relative weights are combined together with respect to all successive hierarchical levels in order to obtain the global weights of all the sub-criteria. A CR of less than and equal to 0.1 shows that the pairwise comparison analysis is acceptable. Otherwise, the analysis should be revised accordingly.

Step 4: Aggregating these relative weights and synthesizing them for the final measurement of the given decision alternatives

For each of the lower elements, their weighted values are added to obtain the overall or global priority. This process of weighing and adding is continued until the final priorities of the alternatives in the bottom-most level are obtained.

The AHP technique give decisions makers more confidence in their decisions (Kontio et al., 1995). The benefits of the AHP technique include:

i. The pairwise comparison process focuses on two criteria at a time and their relation to each other, so respondents will be more comfortable in offering the relative importance for each criterion (Saaty, 2000).
ii. The possibility to measure the consistency in the decision maker’s judgment; it does not make decisions but it guides the analyst in the decision making (Forman & Selly, 2001).
iii. The AHP technique enables decision makers to structure a decision making problem into a hierarchy thereby, helping them to understand and simplify the problem (Jadhav & Sonar, 2009).

iv. The AHP technique is a flexible and powerful tool for handling both qualitative and quantitative multi-criteria problems (Jadhav & Sonar, 2009).

v. The procedure of the AHP technique is applicable to individual as well as group decision making (Jadhav & Sonar, 2009).

The limitations of the AHP technique are:

i. The AHP technique is weak in supporting multi-valued features and it offers an inexact matching of features with requirements (Finkelstein et al., 1996).

ii. The AHP technique is time consuming because of the mathematical calculations and number of pairwise comparisons involved; this increases as the number of alternatives and criteria increases (Jadhav & Sonar, 2009).

iii. The decision makers need to re-evaluate the alternatives when the number of criteria or alternatives are changed (Jadhav & Sonar, 2009)

iv. The ranking of alternatives depends on the alternatives considered for evaluation hence, adding or deleting alternatives, can lead to changes in the final ranking (Jadhav & Sonar, 2009).

The AHP technique has been successfully used in software selection (Kontio, 1996). The application of the AHP technique in several past studies is shown in Table 2.5.

Table 2.5: The Application of the AHP Technique in Software Selection

Authors	**The application**
Zahedi (1985)	Application and Implementation Database Management System Evaluation And Selection Decisions
Dewal et al. (1992)	A decision support method for selection Object Management Systems (OMS)
Kontio (1996)	A Case Study in Applying a Systematic Method for COTS Selection
Lai et al. (1999)	Software selection: a case study of the application of the analytical hierarchical process to the selection of a multimedia authoring system
Teltumbde (2000)	A framework for evaluating ERP projects
Lai et al. (2002)	Group decision making in a multiple criteria environment: A case using the AHP in software selection
Lin & Hsu (2003)	Selection of Internet Advertising Networks Using an Analytical Hierarchy Process and Grey Relational Analysis
Sarkis et al. (2004)	Evaluating and Selecting e-commerce software and communication systems for a supply chain
Wei et al. (2005)	An AHP-based approach to ERP system selection
Chao & Chen (2009)	Evaluation of the criteria and effectiveness of distance e-learning with consistent fuzzy preference relations
Jadhav & Sonar (2011)	Model for evaluation and selection of the software packages: A hybrid knowledge based system approach

2.6.2.3 Fuzzy Analytical Hierarchy Process (Fuzzy AHP) Technique

The Fuzzy AHP technique is an advanced analytical method that was developed from the traditional AHP technique (Kabir & Hasin, 2011). This technique also uses pairwise comparisons to provide a flexible and realistic approach that can accommodate real-life data (Bozdağ et al., 2003). The Fuzzy AHP technique has been adopted so as to accommodate the acknowledged possible uncertainty in the subjective judgments to be made (Tang & Beynon, 2005). The fuzzy evaluation matrix of the criteria is constructed through the pairwise comparison of different attributes that are relevant to the overall objective by using linguistic variables and triangular fuzzy numbers (Kabir & Hasin, 2011). The Fuzzy AHP technique embeds the AHP technique into fuzzy sets. This makes the decision makers more confident in giving their interval judgments rather than a fixed set of value answers (Kaboli et al., 2007).

The Fuzzy AHP technique requires the elements in the decision matrix to be presented in a fuzzy format even though they are crisp in nature (Bozdag et al., 2003). This technique has been used by Buckley (1985) to determine the fuzzy priorities of the comparison ratios whose membership functions were trapezoidal. Using the geometric mean, Buckley (1985) was able to determine the fu zzy priorities of the comparison ratios whose membership functions were trapezoidal. Chang (1996) introduced the use of the Triangular Fuzzy Numbers (TFNs) when providing pairwise comparison judgments in the Fuzzy AHP approach. The extent of the analysis method was then used for the synthetic extent value of the pairwise comparisons (Chang, 1996). In the Fuzzy AHP technique, the TFN represents the uncertain range that might exist in the preferences expressed by the decision maker or experts (Jie et al., 2006). The use of the Triangular Fuzzy Scale in the Fuzzy AHP technique is illustrated in Table 2.6.

Table 2.6: Triangular Fuzzy Conversion Scale

Linguistic Scale For Importance	**Triangular Fuzzy Scale**	**Triangular Fuzzy Reciprocal Scale**
Just Equal(JE)	(1,1,1)	(1,1,1)
Equally Important (EI)	(1,3/2,2)	(2/3,1,2)
Weakly More Important(WMI)	(1,3/2,2)	(1/2,2/3,1)
Strongly More Important (SMI)	(3/2,2,5/2)	(2/5,1/2,2/3)
Very Strongly More Important (VSMI)	(2,5/2,3)	(1/3,2/5,1/2)
Absolutely More Important (AMI)	(5/2,3,7/2)	(2/7,1/3,2/5)

The strength of the Fuzzy AHP technique is its ability to measure the degree of consistency that is present in the subjective managerial judgments. Based on this, the Fuzzy AHP technique can measure the magnitude of the departure from perfect consistency (Canada et al., 1996). Examples of studies using the Fuzzy AHP technique for various applications are shown in Table 2.7.

Table 2.7: Application of Fuzzy AHP technique

Authors	**The application**
Büyükozkan & Feyz'ıoglu (2004)	A fuzzy-logic-based decision-making approach for new product development
Haq & Kannan (2006)	Fuzzy analytical hierarchy process for evaluating and selecting a vendor in a supply chain model
Cheng et al. (2006)	Using Fuzzy Analytical Hierarchy process for multi-criteria Evaluation Model of High-Yield Bonds Investment
Hwang & Hwang (2006)	Computer-Aided Fuzzy-AHP Decision model its application to school Food service problem
Tüysüz & Kahraman (2006)	Project risk evaluation using a Fuzzy Analytic Hierarchy Process: An application to information technology projects
Kreng & Wu (2007)	Evaluation of knowledge portal development tools using a Fuzzy AHP approach : The case of Taiwanese stone industry
Perçin (2008)	Use of Fuzzy AHP for evaluating the benefits of information-sharing decisions in a supply chain
Lee et al. (2008)	A Fuzzy AHP and BSC approach for evaluating performance of IT department in the manufacturing industry in Taiwan
Liu et al. (2009)	E-Learning Platform Evaluation Using Fuzzy AHP
Lai (2010)	Applying Fuzzy AHP to Evaluate the Sustainability of Knowledge-based Virtual Communities in Healthcare Industry
Chatterjee & Mukherjee (2010)	Study of Fuzzy-AHP Model to search the criterion in the evaluation of the best t echnical institutions: A Case Study
Catak et al. (2012)	Fuzzy Analytic Hierarchy Based DBMS Selection In Turkish National Identity Card Project

2.6.3 Summary of the SQM, the COTS Framework and the Evaluation Criteria for Software Evaluation

As was mentioned above, the Software Quality Model (SQM) provides the evaluation criteria for software evaluation. The most commonly used SQM in a software evaluation is the ISO/IEC 9126-1 Quality Model, which is the standard evaluation for a software evaluation. The ISO/IEC 9126-1 Quality Model comprises criteria such as *Functionality, Maintainability, Usability, Reliability, Portability* and *Efficiency* which are considered to be important when evaluating the quality of a software. A summary of the SQM and its evaluation criteria is presented in Table 2.8.

Table 2.8: Summary of the SQM and the Evaluation Criteria for Software Evaluation

	McCall	Boehm	Dromey	ISO /IEC 9126-1	ISO 25010
i. Evaluation Criteria					
Functionality	X		X	X	X
Efficiency	X	X		X	X
Maintainability	X	X	X	X	X
Reliability	X	X	X	X	X
Usability	X			X	X
Portability	X		X	X	X
Reusability	X		X		X

The COTS framework used for the COTS software evaluation including the OTSO, PORE, STACE and CAP was explained above. Overall, the framework provides a sequence of processes for evaluating a software. These processes comprise several stages which are summarized as:

i. Define the evaluation;

ii. Search for COTS products;

iii. Filter the search results;

iv. Evaluate COTS software;

v. Analyze the evaluation data; and

vi. Select the COTS software product that has the best fit with the criteria.

Besides the sequence of processes, the COTS framework also offers a set of criteria which can be used to evaluate the software and they include: *Cost, Vendor, Product Benefit, Organizational and Risk* and *Uncertainty*. Among the criteria, *Cost* criterion was considered to be important and should be included in the evaluation process of a software by organizations since it involves a significant amount of money (Jadhav & Sonar, 2011). The *Vendor* criterion was also noted to be important as it involves the risk element (Nettleton, 2003). There was also an additional caution made by scholars which state that there is a need to ascertain whether there is a 'vendor lock' on a particular software provided. This is because it may incur substantial cost when organizations have intention to shift to another vendor (Siemens, 2006). The *Product Benefit* criterion was also considered as important because it evaluates the benefits of a software product; for example, the availability of the software in increasing user satisfaction and the availability of the software in facilitating the ease of use in system development (Chau, 1995; Pituch & Lee, 2006; Mehlenbacher et al., 2005). The *Organizational* criterion is another important criterion because any criteria that relates to the organization's culture, resources, politics and user acceptance may affect the outcome of the usage (Carvallo & Franch, 2006; Boehm, 1988; Mili et al., 1995).

Finally, the *Uncertainty and Risk* criterion is important in the evaluation process because it affects the possibility of the software failing to meet its goal, thereby, causing losses to the organization concerned (Gülch et al., 2012). The loss incurred may impact on the projects such as diminishing the quality of the end product, increasing operation costs, delaying product or project completion or the complete failure of the software development project (Bandor, 2006). There are risks with system management as the operation is not under the organization's direct control (Ortega et al., 2003; Lipson et al., 2002). For some organizations, the *Uncertainty and Risk* criterion is among the most important criteria to be prioritized in the evaluation and selection of any software product (Bandor, 2006). In the evaluation of the software, insufficient knowledge about the software product criteria could lead to a higher risk of making the wrong choice of software products (Bandor, 2006). Therefore, all these criteria are important and should be considered for software evaluation.

In the evaluation process, the COTS framework commonly uses the AHP technique to evaluate the COTS software. Very few COTS frameworks use prototype in their evaluation.

A summary of the process, evaluation criteria, technique and prototype used are provided in Table 2.9.

Table 2.9: Summary of Process, Evaluation Criteria, Technique and Prototype Used in the COTS Framework

	OTSO	PORE	STACE	CAP
i Process in The Evaluation and Selection COTS				
Define the evaluation criteria	X	X	X	X
Search COTS software	X		X	X
Filter search result	X			X
Evaluate COTS software	X	X	X	X
Select COTS	X	X		X
Other				
ii. Evaluation Criteria				
Functionality			X	X
Efficiency			X	X
Maintainability	X		X	X
Reliability	X		X	X
Usability			X	X
Portability	X		X	X
Reusability				
Cost	X		X	X
Vendor				
Product Benefit	X	X	X	
Risk				X
Other criteria			X	
iii. Evaluation Technique	AHP	AHP	AHP	AHP
iv. Prototype Tool (Yes/No)	No	No	No	Yes

2.7 e-Learning Software Evaluation Model and Framework

In the previous sections, the model, method, approach and framework which provide the criteria and guideline for the evaluation of a software have been presented. This section will review the studies conducted in e-learning and the evaluation and selection of the e-LS.

Chua and Dyson (2004) focused on the evaluation of the e-Learning systems that was already developed for end users. The criteria of the ISO/IEC 9126-1 Quality Model namely, *Usability* was selected to evaluate the usage of the e-learning systems. The Benchmark technique was applied to evaluate the performance of the e-Learning systems. It was noted in the above section that one weakness in the ISO/IEC 9126-1 Quality Model was the *Usability* criteria which is a general criteria used in evaluating any software. To evaluate the e-LS, the criteria needs to be extended since it does not specify any particular teaching and learning characteristics that are needed for good learning. Chua and Dyson (2004) thus recommended that the sub-criteria to be included under *Usability* be based on more specific appearance factors that are based on accepted Human Computer Interaction usability principles. Preece et al. (2002) suggested that the *Usability* criteria include the sub-criteria of consistency, simplicity and legibility which include e font size and use of color (Preece et al., 2002). The sub characteristic of Help should be included as part of *Usability* mainly to ensure that this important factor should not be neglected (Al-Qutaish, 2009).

Costabile et al. (2005) presented the results which were obtained from the observation and analysis of the interactions of people with e-learning applications. The aim of Costabile et al. (2005) study was to develop a methodology for evaluating the e-Learning applications. A preliminary set of the *Usability* criteria which also captures the features of e-learning was presented. In order to go deeper into the pedagogical aspects and the semantic contents, experts from the education and science domains were included. The evaluation of the e-Learning system, from a pedagogical point of view, for instance, concerns the coherence and the congruence of the learning path design. Costabile et al. (2005) study adopted the Systematic Usability Evaluation (SUE) inspection technique which introduces evaluation patterns that drive the inspectors' activities during the evaluation. The inspection has a central role: each evaluation process should start with the expert evaluators inspecting the application. This is then followed by the user testing step which may be performed in more critical cases when the expert evaluators feel the need to be more objective in their evaluation. The limitation of this study is the lack of a proper guideline and criteria that can be used to evaluate learning effectiveness.

In another study, Colace and De Santo (2008) proposed a model for describing, characterizing and selecting the e-Learning platform. The e-Learning system selection was based on a multiple criteria decision-making problem which needs to be addressed objectively. It also needs to take into consideration the relative weights of the criteria for any organization (Colace & De Santo, 2008). This model that was recommended by Colace and De Santo (2008) involves three criteria for evaluating the e-LS which include *Technological*, *Pedagogical* and *Usability*. The focus of the evaluation was on the commercial e-LS. Collace and De Santo (2008) mentioned that the multi criteria problem is a decision hierarchy that can be solved through the AHP technique. Nonetheless, the model they developed only focused on the technical aspect of the software product.

Shee and Wang (2008) proposed the asynchronous e-learning system evaluation based on the perspective of user satisfaction. The results obtained from their study identified a total of 17 items which were applicable in measuring user satisfaction in an e-learning environment. These were then classified into the dimensions of content, personalization, learning community and learner interface. The MCDM framework was constructed and a survey was conducted to evaluate the web based e-Learning system. The researchers also used the AHP technique to analyse their data which showed that the most important dimension of the decision criteria was the learner's interface (Shee & Wang, 2006).

A study conducted by García (2006) provided a framework that was based on the use of the SCORM standard specifications. The framework was developed based on a Learning Platform Evaluation Model that assumes three main areas of functionality for any learning platform which include content, communication and management. The framework was applied to compare the functionalities of two popular LMS that supported the SCORM specifications. The framework allowed the instructors to elaborate the benchmark tests for evaluating the e-Learning platform. To do this, a benchmark prototype was developed to access the evaluation framework. The prototype was used to test two widely used e-learning platforms (García, 2006).

Lanzilotti et al. (2006) also proposed a framework that was based on Technology, Interaction, Content, and Services (TICS). This was developed based on the concept of the quality of e-learning systems which involve technology, interactions, contents and offered services that should comply with the expectations of learners and teachers (Lanzilotti et al., 2006). The TICS framework focused on the most important aspects to be considered in the evaluation of an e-learning system which is user-system interaction. In terms of technology, the researchers focused on the hypermedial aspect. In this study, the Interaction criteria focused on two aspects namely, presentation and user activity; the Content criteria focused on the educational process and the Services criteria focused on the application's proactivity. Lazilotti et al. (2006) were also able to develop a guideline which addresses the TICS besides proposing an evaluation methodology called the e-Learning Systematic Evaluation (e-LSE).

Liu et al. (2009) proposed evaluating the e-Learning platform by using the Fuzzy AHP technique. They shortlisted three evaluation criteria namely, learning system, organizing system and knowledge system for the evaluation process. A case study was conducted in the evaluation by using a survey/questionnaire approach which was manually conducted. Experts were asked to answer the Fuzzy AHP questionnaire and based on the outcome of the survey, the Fuzzy AHP model was then constructed and the three criteria were selected for use in the evaluation process. The Fuzzy AHP technique involves many difficult processes. A manual approach was also conducted for the pairwise comparison through the Fuzzy AHP technique and this process would require a period of time for processing, if many criteria were involved. As stated above, traditional AHP technique would expect the evaluation values to be converted into triangle fuzzy numbers so as to solve the fuzzy problem. In order to obtain priority weight from the pairwise comparison judgment by experts, the Fuzzy AHP technique involves the application of complex mathematical calculation and formula. As such, a tool is appropriate to assist in utilizing the manual of Fuzzy AHP mathematical calculation but enable to support the complexity in the evaluation process of e-LS.

Chao and Chen (2009) proposed a method called the Consistent Fuzzy Preference Relation (CFPR) that is in the AHP structure to find the weight of the affecting criteria in a distance e-learning system. The CFPR in the AHP model was considered to be a computational simplicity because it preserves the consistency of comparisons when compared with the traditional AHP technique. The five main criteria included in the method encompass: the e-learning materials, the quality of the web learning platform, the synchronous learning, the learning record and self-learning. The structure of the criteria uses the AHP model. Here, computational simplicity means that it only involves basic calculations such as addition, subtraction, multiplication, and division followed by the mathematical logarithm functions for transformation. Hence, this method is considered a simple and easy method that can be used to weigh the factors noted in an e-learning program or system, besides evaluating the overall effectiveness of e-learning.

Padayachee et al. (2010) proposed the adoption of the ISO/IEC 9126-1 Quality Model for user evaluation of the CMSs. It was claimed that the generic external systems quality criteria and the sub-criteria of the ISO/IEC 9126-1 Quality Model were appropriate for user evaluation of the CMSs selected. The characteristics of the external quality system (sub) and the corresponding quality criteria can be used to test the theoretical proposition which states that a higher external quality would imply a higher quality in use for users of the e-Learning systems. The quality criteria corresponding to the external quality (sub) criteria can be used to test the (sub) criteria that strongly influence user satisfaction in the e-Learning systems. Measuring the external quality to examine its effect on the 'quality in use' would help system designers to make the necessary additions or revisions when contemplating to design contents and features for e-Learning so as to improve users' views of the quality. Evaluators, testers and developers would be able to evaluate the software's external quality as well as address any external quality issues. Educators, educational administrators and higher education institutions intending to adopt the CMSs in implementing e-Learning have a vested interest in users' evaluation of the system's 'quality in use'. This information can be used by the decision makers in the decision making process with regards to the choice of the CMS. Nonetheless, there is one limitation in this study – it focused only on one characteristic of quality in use namely, user satisfaction.

Abdellatief et al. (2011) recommended a new technique to evaluate e-learning website quality from the developer's view. Their technique adopts the weights of quality characteristics which were obtained from the carefully selected questionnaires' of professional website developers. The researchers proposed that four quality criteria be considered and they include *Service Content*, *System Functionality*, *Information Technology* and *System Reliability*. Following the structure of the ISO/IEC 9126-1 Quality Model, 11 sub-criteria with its attributes, were proposed. The AHP technique was used in the evaluation process and the validation was presented. It appears that the proposed technique may be useful and effective for ensuring that high quality systems are developed. However, their study only concentrated on the evaluating the website developers' perspective.

From all the studies provided above, it appears that past literature had also concentrated on the e-LS evaluation; they have also used the evaluation frameworks proposed by others as well as developed the evaluation models and the criteria to be used in an e-LS evaluation process. Clearly, some of the framework and model focused on evaluating examples of the e-LS encompassing the LMS and the CMS. The evaluation criteria used also varied from study to study. While some studies focused on the ISO/IEC 9126-1 Quality Model, others focused on the evaluation of the e-Learning platform or other ready-made e-LSs. Further, the evaluation criteria included in the evaluation process also ranged from those selected from the ISO/IEC 9126-1 Quality Model to other criteria that were unique to the educational domain encompassing elements such as *Pedagogy, Adaptivity* and *Personalization.*

Undoubtedly, most of the studies had chosen to focus on the needs of instructors and learners in the evaluation of the e-Learning platform. Nonetheless, some organizations chose to use the e-LS to develop e-Learning applications from scratch (Drigas et al., 2006). This may be because such organizations may require other e-LS products that can be used in the development of e-Learning applications based on their respective needs and use. Therefore, the evaluation criteria of the e-LS should be further extended to enable various organizations to evaluate as many types of the e-LS as possible and this may be accomplished through the assistance of other deployment tool. In that regard, the criteria extracted from the COTS framework may be included in the evaluation of the e-LS. This would ensure that a more comprehensive criteria is available as organizations are supported in the e-LS evaluation process. A summary of the various e-LS evaluation studies is illustrated in Table 2.10.

Table 2.10: Summary of e-LS Evaluation

Authors	**Criteria**	**Evaluation Technique**	**Evaluation Domain**	**Tool**
Chua and Dyson (2004)	*-Functionality* *-Maintainability* *-Usability* *-Reliability* *-Efficiency*	Benchmark	The usage of e-Learning system	No
Costabile et al. (2005)	*-Usability* *-Pedagogigal*	Systematic Usability Evaluation	The evaluation of e-Learning application	No
Shee & Wang (2006)	*-Learner Interface* *-Learning Community* *-System Content* *-Personalization*	AHP Technique	User satisfaction of e-Learning systems	No
Garcia (2006)	*-Functionality*	Benchmark	Functionality of e-Learning Platform	No
Lanzilotti et al. (2006)	*-Usability*	Usability Evaluation	User satisfaction of e-Learning systems	No
Colace et al. (2006)	*-Pedagogical* *-Technological* *-Usability*	AHP	Technical aspects of e-LS	No
Liu et al. (2009)	*-Learning* *-Organizing* *-Knowledge*	Fuzzy AHP Questionnaire	Feasibility of e-Learning Platform	No
Padayachee et al. (2010)	*- Functionality* *- Reliability* *- Usability* *- Efficiency*	Questionnaire	The adoption of the ISO/IEC 9126-1 Quality Model criteria and sub criteria appropriate for user evaluation of Content Management Systems	No
Abdellatief et al. (2010)	*- Service Content* *-System Functionality* *- Information Technology* *- System Reliability*	AHP Technique	-Evaluate e-learning web site quality from developer's view	No

2.8 Existing Tools in Software Evaluation

In this section, several available tools that can be used for software evaluations are described.

2.8.1 Description, Evaluation and Selection of the COTS Components (DesCOTS)

The DesCOTS is a software for supporting the COTS selection process and it is based on several software quality models (Grau et al., 2004). The DesCOTS has been used successfully in several applications such as mail server systems, Enterprise Resource

Planning (ERP) systems, and document management systems (Carvallo et al., 2003; Botella et al., 2003; Carvallo et al., 2004). It also supports the definition of the selection criteria, the classification of the COTS domains, the evaluation of the COTS components, the management of the requirements and the selection process itself. The DesCOTS can be used as independent tools which give them the ability to be used to support other software engineering practices such as software quality assurance during software development (Dromey, 1996; Bøegh et al., 1999). The DesCOTS can utilize data that are obtained from other systems. Then, the data can be integrated into the DesCOTS. The DesCOTS provides facilities for defining the methods of use; it can also declare the steps incurred linking them to the particular features offered by the tool (Grau et al., 2004). The DesCOTS applies the ISO/IEC 9126-1 Quality Model and it uses the AHP technique to assist in the evaluation of the COTS components. The DesCOTS also rely on criteria extracted from the ISO/IEC 9126-1 Quality Model. The COTS software evaluation tool have been used by others to provide support in the evaluation and selection process of the software.

2.8.2 Easy Way LMS (EW-LMS)

A few tools have been developed for the evaluation process of the e-LS. One such tool is the Easy Way LMS (EW-LMS) which is a web based decision support system that was developed by Cavus and Ala'a (2009) to help users such as administrators and instructors to choose the most suitable LMS for their learners. The evaluation criteria applied are based on the features of the LMS. An artificial intelligence algorithm namely, the linear weight attribute model, is used to weigh and rank the features in the evaluation process (Cavus & Ala'a, 2009). These features are then used as the evaluation criteria to enable users to evaluate the systems. Fifty-two features were used in the system for the following popular LMSs: Moodle, ATutor, Blackboard, WebCT, and Claroline. These features were classified into Pedagogical Factor, Learner Environment, Instructor Tools, Course and Curriculum Design, Administrator Tools and Technical Specification. The EW-LMS is the most suitable tool to be used to evaluate systems that are already in use for example, the LMS. This is because the evaluation criteria are dependent on the product features themselves. The EW-LMS can be used by administrators and instructors who wish to select currently available LMS for their own and their learners' use. The EW-MS tool was deliberately developed for the e-LS evaluation particularly, the evaluation of the LMS. Since there are many types of e-LS available, it would seem logical that the current evaluation criteria used be further revised so as to include more comprehensive evaluation criteria that can be used in various evaluation processes as well as by different users. These extensive set of evaluation criteria can then be stored in an evaluation tool to cater to the different users in a generation where the development of new e-Learning application and materials are rapidly increasing.

2.8.3 Tool for Ranking Modern Educational Systems' Success Criteria

Mehregan et al., (2011) introduced the Fuzzy AHP technique as a method to rank modern educational systems' success criteria for evaluating the performance of e-learning. They identified and prioritized the preliminary e-learning Critical Success Factors (CSF) or enablers that need to be given focus by universities and other educational institutes. These criteria include student characteristics, information technology quality, instructor characteristics, content quality and educational institutes' support and participation interaction. The questionnaire proposed also contains a proposed CSF indicator and their criteria. The questionnaires were then distributed among sample e-learners who were asked to compare the importance of each CSF indicator with another one. They were also asked to compare the importance of each criterion under each indicator with another one at the same indicator. Some steps of the Fuzzy AHP technique were applied as a material in the evaluation process of the CSFs. The users used the questionnaire as a tool to evaluate the criteria. No support tool was provided in the evaluation phase for the users. The Fuzzy AHP technique used in the tool only focused on the calculation of weight pairwise comparison judgment by the users. The tool was also used to calculate the final score of each indicator and criterion. The final score of the pairwise comparison among the indicators and criteria were then input to the Fuzzy AHP tool and the tool only calculates the priority of the criteria. Once the evaluation data were gathered from the users via the questionnaire, they were transferred into the tool for calculation. As has been explained before, this process is time consuming and may affect the outcome of the analysis. Therefore, a more flexible tool that could assist the users and the researchers in the evaluation process using the Fuzzy AHP technique is imperative.

2.9 Research Gaps

The evaluation of any software product that is intended to be used in an e-LS is important because it can help to ensure that the right and appropriate products are purchased or acquired and that these suit user's needs and fulfil organizations goals and budget. However, the evaluation and selection process of a software is a complex task which involves many processes. These processes include i. Planning the evaluation and requirement definition; ii. Preliminary investigation; iii. Establishing the evaluation criteria; iv. Shortlisting of software; v. Evaluating of software; vi. Selecting of software; vi. Negotiating with vendor; and vii. Purchasing of software. As can be noted a process that encompass so many stages can consume a lot of time and possibly a lot of money too not considering the personnel that might be involved. Such a long process can eat into the time for users who will need the e-LS to be competitive and at par with others around the world. The longer such a e-LS is delayed, the more users are deprived of the use of the technology to acquire the skills and knowledge that are necessary to raise their standards and quality as human capital for the country.

According to Nagi (2006), with the demand of e-Learning implementation and the rapid increase of e-LS products, the evaluation process is made even more complicated. Moreover, as has been explained, the evaluation of the e-LS involves many processes, criteria and techniques. Thus, the skill to perform the evaluation needs to be enhanced both for developers of the system as well as organizations implementing the e-LS and the end users. In other words, to shorten or to simplify the evaluation process, a more standardized guideline and a more simple and easy to follow procedure should be developed. Thus, far, the evaluation process of the e-LS has been unstandardized; it follows a diverse desire of the organizations; it may be dependent on the vendors' recommendation or the software developers' suggestions. All of these may not create an evaluation process that is objective and can offer an ultimate result that is accurate and precise as well as fulfils the various needs of the organizations. This trend makes the evaluation and selection of the e-LS a difficult process and a time consuming one.

Existing software evaluation approaches showed that most SQM was based on the evaluation criteria taken from the ISO/IEC 9126-1 Quality Model, such as *Functionality*, *Maintainability*, *Usability*, *Reliability*, *Portability* and *Efficiency*. However, the general criteria provided in the ISO/IEC 9126-1 Quality Model may not be adequate enough to support the varieties of e-LS evaluations including the LMS, LMCS and other Deployment tools. A refinement of the ISO/IEC 9126-1 Quality Model evaluation criteria needs to be undertaken to suit the particular types of e-LS evaluation. Thus far, most e-LS studies have covered the evaluation of the e-Learning system or platform, an example of which is the LMS. However, it is suggested that the criteria for evaluating the e-Learning platform should be slightly different from that of a general software evaluation approach because of the learning characteristics of the e-LS. Criteria that are used to evaluate any e-LS that are intended for the e-Learning platform should be suitable for the users of the e-Learning platform which include instructors and learners. To date, no study had focused on looking at the criteria of the deployment tools even though such criteria may be suitable for other parties such as the e-LS developers. It is deduced that these stakeholders might use e-Learning not only to customize ready-made e-LS but also for developing a new set of e-LS using Java for their own use. Thus far, the criteria found in the COTS framework include *Cost, Vendor, Product Benefit, Organizational* and *Risk and Uncertainty*. These criteria are equally important to be included in the evaluation process of the e-LS because the criteria encompass the basic aspects of investment. Nonetheless, the criteria and sub-criteria that should be included for an evaluation process may also be subjective and they also vary from user to user and organization to organization. Since this is a realistic phenomenon, users including organizations will be extremely challenged when determining which criteria are more important for the evaluation process. This gap is, fortunately, filled by the consensus of the experts' opinions on the appropriate criteria and sub-criteria of the e-LS, which had been obtained from the Delphi survey conducted.

Besides the evaluation criteria which studies have been able to identify, the evaluation techniques used were also reported in the respective studies. It appears that most software evaluation process used the MCDM technique such as the AHP technique. The COTS framework, for example, the OTSO, PORE, STACE and CAP, tend to use the MCDM technique, in particular the AHP as their evaluation technique. This technique relies on pairwise comparison by using crisp or exact numbers as the criteria weights. However, any human preference model does not always make the most certain model since decision makers, in some circumstances, may be reluctant or unable to assign crisp or exact numerical values to the comparison judgments (Wu et al., 2006). Moreover, the AHP technique may be a good technique but it also has its limitations. It has been stated that the AHP technique is unable to evaluate the uncertainty characteristic of the criteria, thus, the Fuzzy AHP technique, may be used as an alternative.

Besides the Fuzzy AHP and the AHP techniques discussed, existing studies (Wu et al., 2006; Nagi, 2006) also noted that the DesCOTS tool provide criteria for software evaluation. It has been noted that the criteria that were contained within the COTS software tend to rely on the ISO/IEC 9126-1 Quality Model, whose criteria tend to be general and since the general tool for evaluating the COTS criteria is inadequate for evaluating the e-LS, other criteria had to be set up under the DesCOTS tool.

The EW-LMS was developed as a tool to evaluate one type of e-LS namely, the LMS products. The tool provides support for administrators and instructor to select the LMS. As discussed in 2.3, the LMS is a ready-made type e-LS which can be used by administrators and instructors as well as developers and researchers. In general, most administrators and instructors would require a customized e-LS which can be used to support e-Learning.

In contrast, software developers and researchers may need the e-LS to develop other e-Learning applications based on their organizations' needs. In order to develop such e-Learning applications, a set of deployment tools need to be used. As such, a more comprehensive e-LS criteria would be beneficial in providing organizations with better options of criteria which can then be used to support their respective needs when evaluating a particular e-LS product.

Thus far, Liu et al. (2009) have applied the Fuzzy AHP technique in evaluating an e-Learning platform. However, the criteria used were not comprehensive because most of the criteria focused only on the learning, organizing and knowledge of the platform. In addition, the manual approach used by the scholars to administer and analyze the Fuzzy AHP questionnaire also consumed too much time. Expanding on this, the manual analysis of the pairwise comparisons also seemed to be very cumbersome due to the mathematical complexities involved especially as the criteria used increased. To overcome the complexities involved, an appropriate tool could be used to assist in the evaluation process, especially as a means to replace the manual mathematical calculations.

Mehregan et al. (2011) introduced the Fuzzy AHP tool to rank the success criteria of a modern educational system in evaluating the performance of e-Learning. They applied the Fuzzy AHP technique and used a questionnaire to evaluate the importance of each CSF indicator and its comparison to each other. The Fuzzy AHP technique used in the tool only focused on assisting the researcher in calculating the formula of the Fuzzy AHP. Consequently, this method was found to be time consuming since it required a combination of questionnaires and Fuzzy tools that were needed for the calculations. An adequate tool should be able to measure the effectiveness of the entire evaluation process hence, the research gap model is schematically illustrated in Figure 2.13.

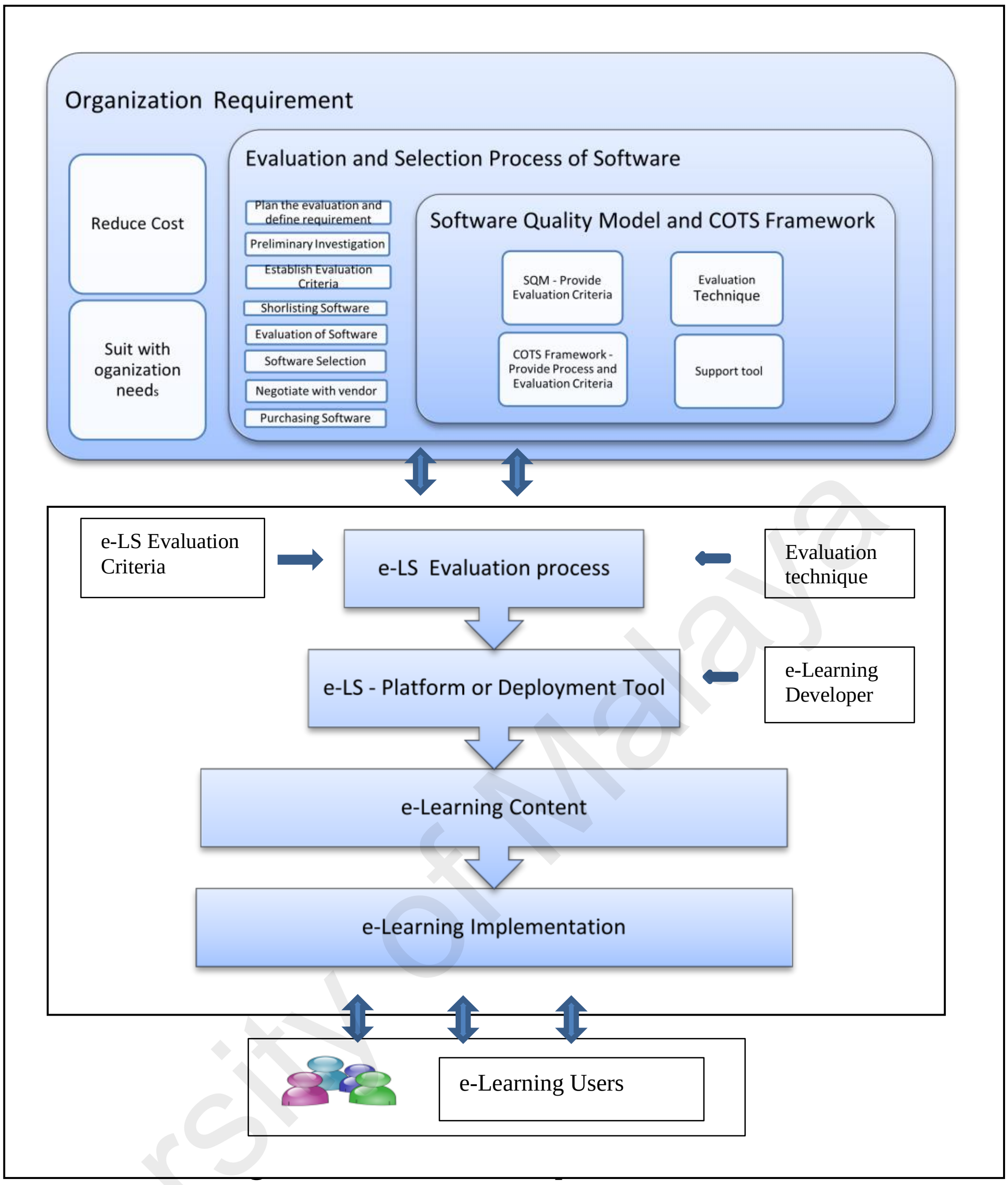


Figure 2.13: Research Gap

From the literature review made, the research gaps highlighted can be classified as follows:

i. *There is no standard e-LS evaluation framework that consists of an valuation process using appropriate techniques which can serve as a guideline for organizations to follow when making an e-LS evaluation.*

ii. *The existing SQM and COTS evaluation frameworks do not provide sufficient evaluation criteria which are important for evaluating the varieties of e-LS. The current existing e-LS evaluation framework and model only* *provide criteria that focused on evaluating specific types of e-LS, for example, the LMS.*

iii. *Current tools do not provide sufficient support to automate steps as a guideline for the evaluation process and to provide specific criteria and sub-criteria of the e-LS which can assist organizations in evaluating the e-LS.*

As a consequence of the above research gaps, this study is motivated towards formulating an e-LS framework for e-LS evaluation. Such a framework should also consist of a systematic process, the necessary evaluation criteria and the appropriate technique supported with a software tool that can assist in the evaluation process of the e-LS. This proposed framework is useful as a tool in assisting the evaluation process.

2.10 Summary

This chapter consists of the literature review that is related to the topic of this study. The review covered areas encompassing e-Learning and the e-LS followed by an overview discussing the importance of evaluating and selecting the e-LS. The review also identified the general processes used in the evaluation and selection for software acquisition. It also revealed the various stages of the evaluation process including planning the evaluation and the requirement definition, preliminary investigation, establishing of evaluation criteria, shortlisting of software, evaluating of software, selecting of software, negotiating with vendors and purchasing of software. The evaluation process also considered the complexity and difficulty incurred due to the lack of a proper evaluation framework that can serve as a guideline, the inadequate evaluation criteria as well as the lack of a suitable technique that can be used in the evaluation process. The SQM and COTS frameworks which comprise general evaluation criteria for guideline in the evaluation process were also elaborated. Current existing software evaluation techniques such as the Benchmark and the MCDM were also discussed. From the literature review made, it was noted that the most commonly used evaluation technique for software selection was the AHP technique. Further to that, some tools that could be used to assist in the evaluation process of a software including the evaluation of the e-LS were also highlighted. Finally, the research gaps that motivated the undertaking of this study were also listed.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction

This chapter presents the research methodology. The overall research process, methods, and the outcomes related to are discussed. Figure 3.1 illustrates the research methodology.

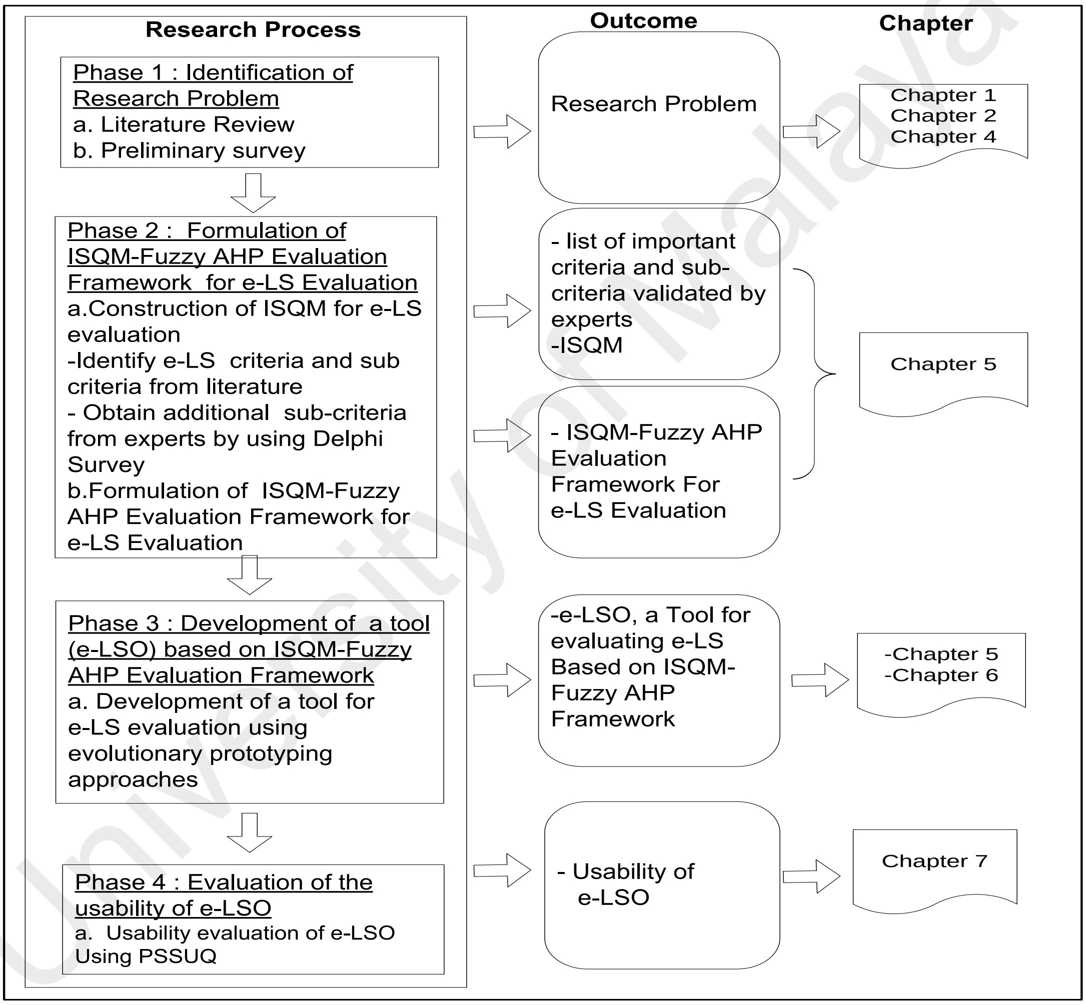


Figure 3.1: Research Methodology

The overall research methodology consists of four phases, namely:

i. Phase 1: Identification of Research Problem

ii. Phase 2: Formulation of the ISQM-Fuzzy AHP Evaluation Framework for e-LS Evaluation

iii. Phase 3: Development of a Tool Based on the ISQM-Fuzzy AHP Evaluation Framework for e-LS Evaluation

iv. Phase 4: Evaluation of the Usability of the e-LSO

3.2 Phase 1: Identification of Research Problem

Phase 1 discussed the identification of the research problem. To accomplish this task, an in-depth review of past research work related to the current study was made. Following this, a preliminary survey was conducted with the goal of investigating the limitation of the current practices noted in the evaluation and selection of the e-LS.

3.2.1 Literature Review

The scope of the literature review covers e-Learning, e-LS and their benefits; the software evaluation and selection process; investigation of the software evaluation and the selection approaches used such as the quality model, the COTS software based framework, and the software evaluation techniques applied. As the domain of this study is on e-LS, past studies focusing on the evaluation of the e-LS were also reviewed. Finally, the research issues were highlighted so as to justify the need for this study to be conducted. All the information collected from literature have been explained in detail in Chapter 2.

3.2.2 Preliminary Survey

The goal of conducting the preliminary survey was to understand the limitations of the current practices noted in the evaluation and selection process of the e-LS. A survey approach is deemed to be an acceptable research tool that can be used on a community so as to gain their feedback on attitudes, preferences and opinions about a particular issue (Rea & Parker, 2014). Results from the survey are used to justify the need for the formulation of the e-LS evaluation framework and the development of the tool in this study. The process of conducting the preliminary survey involved four parts which are described below.

3.2.2.1 Preliminary Survey: Questionnaire Construction

To undertake the preliminary survey, a questionnaire was constructed as a research instrument. The construction of the questionnaire was subjected to several processes, including question development, questionnaire review, modification and validation. Some processes such as the question development stage had to undergo several revisions so as to ensure that the questions covered the scope of the preliminary survey. The questionnaire was then divided into two sections: Section A and Section B.

Section A focused on the demographic background of the respondents who were Technical Experts, Decision Makers as well as Academicians/Researchers. All of them possess knowledge and experience in the implementation of e-Learning in their respective organizations. The experts were categorized based on their job function in their organization. Technical Experts were those involved in the implementation of as well as the development of various technical issues in their respective organizations. Academicians/Researchers were those actively involved in e-Learning research while Decision Makers involved those who make decisions in selecting the e-LS for e-Learning implementation in their respective organizations. Doctoral or PhD candidates whose works involved e-Learning were also invited to participate in the survey even if their experience was less than five years. This is because of their active participation in the research area of e-Learning. The demographic background and the category of the experts were presented in section 4.2. In the survey, the experts were required to provide information about their organizations, designations, contact numbers and email addresses. The demographic information also required information revealing the type of organizations, job functions, highest educational attainment and working experiences. This information is to ensure that the experts chosen have the relevant academic experience and qualifications.

Section B involved questions which the experts were required to answer. These questions were related to the current practices of their organizations in evaluating and selecting the e-LS. The survey focused on collecting information pertaining to:

i. the implementation of e-Learning;
ii. stages and methods in the evaluation and selection of the e-LS;
iii. the evaluation criteria;
iv. the tool for the evaluation and selection of the e-LS; and
v. the problems encountered in the evaluation and selection of the e-LS.

The questionnaire used for the preliminary survey is included in Appendix A.

3.2.2.2 Preliminary Survey: Validity

The questionnaire used in the preliminary survey was assured for its validity, which in this case, refers to the degree to which a test actually measures what it is supposed to measure (Sartori & Pasini, 2007). One of the criteria for testing the questionnaire's validity is to guarantee its content validity which is the extent to which the survey provides adequate coverage of the topic under study (Emory & Cooper, 1991). A validity test is valid if it measures what it purports to measure (Friedland, 2002). To determine the clarity of the questions, the questionnaire was reviewed in a pilot study involving three respondents who were e-Learning experts. A pilot study is a process of carrying out a study with a small sample (Varkevisser et al., 1993) to ensure that the questionnaire is able to gather the same kind of information as it expects to from the experts involved the actual study. This means that the importance of the words and concepts used are emphasized. Based on the feedback of the pilot study, some modifications were made to improve the contents of the questionnaire before they were distributed to the selected respondents.

3.2.2.3 Preliminary Survey: Respondents Among Experts

In this study, the reliability of the respondents and organizations were ensured and not compromised. All the respondents selected for this study were experts in the area of e-Learning. An expert is any individual who has the relevant knowledge and experience of a particular topic (Thangaratinam & Redman, 2005). In considering the number of respondents to be involved, Louis et al. (2007) noted that a sample size of 30 is considered the minimum number that is suitable for statistical analysis of the data. In the current study, information regarding the respective experts were obtained from their organizations' web site. A total number of 250 experts were contacted via the email or through telephone calls. Those experts who were contacted through the email were requested to complete an online questionnaire while those experts who were contacted through telephones were requested for appointments so as to be able to meet them with the questionnaire concerned. Out of 250 experts who were contacted, only 53 responded, thereby, indicating a response rate of 21.2%. Of these 53, only 50 of them completed the questionnaire as required. Appendix B displays the 50 experts who participated in the preliminary survey.

As mentioned earlier, the selected experts were e-Learning practitioners and they also possess the knowledge and experience in e-Learning as well as the e-LS. They were involved in the evaluation and selection of the e-LS products. Based on this profile, the experts were recruited from eight public universities, two private universities, five private organizations and one government agency and they simultaneously represent the selected organizations in Malaysia which also implement e-Learning. Among these experts, some had been introduced by the respective staff to participate in the survey when the preliminary survey was conducted at the respective organizations.

Among the Academicians/Researchers who were involved with the survey, some had been appointed by the universities to serve as the Director or Coordinator in their respective e-Learning units. They were responsible for the evaluation and selection of the e-LS to be used for the e-Learning implementation. Some of the Academicians/Researchers were also academicians serving as researchers in e-Learning. Among those selected for participation, four were doctoral (PhD) postgraduates who were conducting research on e-Learning. Other than the Academicians/Researchers, the others were the Technical Experts and the Decision Makers. They were also invited to participate in the survey so as to ensure that the input comes from various other experts. The demographic background of the experts will be discussed in detail in Chapter 4.

3.2.3 Software Tools for Data Analysis in Phase 1

The descriptive statistics taken from SPSS version 15.0 were used to analyse the results of the questionnaire responses. In total, 50 experts were involved. The results of the preliminary survey will be explained in Chapter 4.

3.3 Phase 2: Formulation of the ISQM-Fuzzy AHP Evaluation Framework for the e-LS Evaluation

Phase 2 explained the construction of the ISQM and the formulation of the ISQM-Fuzzy AHP evaluation framework for the e-LS evaluation.

3.3.1 Construction of the ISQM for the e-LS Evaluation

The construction of the ISQM for the e-LS evaluation involved two steps:

i. Identifying the e-LS evaluation criteria and sub-criteria from the literature review;

ii. Obtaining the additional sub-criteria from the experts by using the Delphi survey.

3.3.1.1 Identifying e-LS Evaluation Criteria and Sub-criteria from Literature Review

The systematic review guideline made by Kitchenham (2007) was used to conduct the literature review. As the objective is to identify the evaluation criteria and the sub-criteria for evaluating the e-LS, several issues were considered prior to conducting the literature review. They are as follows:

a. Sources

The information for e-LS criteria was collected from various sources such as academic journals, reference books, web sites and thesis dissertations. The ISO/IEC 9126-1 Quality Model articles was also selected for the literature review.

b. Paper Selection

The search results were based on the review of publications which were related to software selection issues; it also include the manual reading of titles and abstracts of potentially relevant published journals and conference papers. The main criterion used in filtering the literature review was that the publications must describe the software evaluation and selection stages, the software evaluation and selection process, the software acquisition, the COTS software, e-Learning, e-Learning software, e-Learning software evaluation and the decision making tools involved.

c. Validity of Literature

The main threat to the validity of the literature review was the inclusion of all the publications related to this study. Thus, the focus were made on publications that were related to the evaluation and selection of software products, the evaluation and selection of the COTS software and the evaluation and selection of e-Learning software.

d. The Search Strategy

The e-LS evaluation criteria search was made based on the review of publications extracted from academic journals, conference proceedings and technical reports from electronic databases. This activity includes utilizing Google Scholar, Web of Science and the ISI Web of Knowledge websites. In addition, electronic databases such as Elsevier's Science Direct, the IEEE Xplore, the ACM portal and Springer-Verlag's Link were also explored. Articles on Software Engineering published in the proceedings of the IEEE, Springer-Verlag, the International conference on COTS-Based software selection, which are all relevant to the area of this study, were also included.

e. The Search Terms

The search terms used were ‘‘e-Learning implementation”, ‘‘e-Learning software category”, “e-Learning software products”,” software evaluation criteria”, ‘‘e-Learning Software evaluation”, ‘‘e-Learning systems criteria”, ‘‘evaluating and selecting software packages”, ‘‘ISO/IEC9126-1 Quality Model”, “evaluating Commercial of the shelf products”, “method for evaluating and selecting software packages”, ‘‘criteria for evaluating and selecting software packages", ‘‘software evaluation criteria" and ‘‘software selection process".

f. Data Extraction and Reporting

The literature review has covered topics on the evaluation and selection of software, software evaluation criteria, COTS software evaluation, and e-LS evaluation. Based on the reading of abstracts and contents of articles, 250 academic articles were found to be relevant for extracting data about the e-LS evaluation criteria and sub-criteria, at the initial phase. After filtering, a final list of 50 related articles were found to be specifically related to the evaluation criteria of software including e-LS. The final list of the articles was summarized in Table 5.1. The result of the data obtained were then analyzed and reported. The section below discusses the Delphi Survey

3.3.1.2 Obtaining additional Sub-Criteria from Experts by Using Delphi Survey

a. Delphi Method

The Delphi method was developed by the Rand Corporation in the 1950s (Dalkey & Helmer, 1963). It is considered a reliable qualitative research method that has potentials for forecasting complex issues, problem solving, decision making, and group consensus which can be applied to a wide variety of area (Turoff et al., 1982; Rowe & Wright, 1999; Skulmoski et al., 2007; Gülch et al., 2012) including in e-Learning (Bhuasiri et al., 2012). The Delphi method is generally characterized by three important features (Legenre, 2005) which are:

- Anonymous group interaction and responses;
- Multiple iteration or rounds of questionnaires or other means of data collection with researcher controlled statistical group responses and feedback; and
- Presentation of statistical group responses.

The Delphi method allows an iterative and systematic collection of experts' opinion through a series of intensive questionnaire which is interspersed with controlled opinion feedback (Ononiwu, 2013). Delphi method is derived from the understanding that decisions collected from a group of experts are more accurate than decisions collected from unstructured groups. Delphi method relies on a panel of experts to answer the questionnaire in two or more rounds survey with the objective of ranking particular issues identified (Martino, 1993).

In this study, the term Delphi survey is used to represent the survey that was conducted through the Delphi method.

b. Respondents in Delphi Survey

Respondents involved in the Delphi survey should be selected from a group of experts. In their recommendations, Hoffer et al. (2011) state that the number of participants in a Delphi survey should range from 10 to 50 experts in order to ensure the validity of the results obtained. In a Delphi method, respondents should consist of a homogenous group of experts who are from the same discipline area and their number may vary from 10 to 15 experts (Satzinger et al., 2011). In this study, 31 respondents took part in both rounds of the Delphi survey. These experts were grouped into 11 Technical Experts, 10 Decision Makers and 10 Academicians/Researchers (see Appendix E). The experts' opinions were utilized to provide and validate the evaluation criteria which had been obtained from various sources.

c. Number of Rounds in Delphi Survey

Determining the number of rounds in a Delphi survey is necessary so as to reach a stable level of consensus. This is crucial for the success of a Delphi method (Martino, 1993). The number of rounds in a Delphi survey can vary from two to four rounds

(Martino, 1993). In this study, only two rounds of the Delphi survey were conducted as the consensus was already obtained by the second round.

d. Delphi Survey Questionnaire Construction

The evaluation criteria identified from the literature review were compiled in the questionnaire for the Delphi survey. Two sets of questionnaire were developed.

The first set of the questionnaire for Round 1 was divided into three sections:

- Section A: The demographic background of the experts was collected. The demographic characteristics of the experts include the types of organization, job function, educational attainment and years of experience in the field of Information Technology.
- Section B: The experts were required to rank the evaluation criteria that were identified from the literature review. The responses were recorded on a 5-point Likert-type scale which identifies each criterion and sub-criterion of the e-learning software products as "Extremely Important"(5), "Most Important" (4), "Moderately Important" (3)","Important" (2) and "Not Important" (1).

  In the last part of section B, the experts were requested to provide each criterion with new items pertaining to the sub-criteria.
- Section C: The experts were invited to provide new criteria and its sub-criteria for the evaluation of the e-LS products.

The questionnaire used in Round 1 of Delphi survey is attached in Appendix C. The questionnaire used in Round 2 consists of the same information collected in Round 1. The questionnaire for Round 2 is included in Appendix D.

e. Questionnaire Reliability

Before the questionnaire was sent to the experts, a pilot study was conducted to ensure its reliability. Reliability can be translated as the consistency of the measurement across the variety of items listed in an instrument (Sekaran, 2000). The correlation value between the questions in an instrument would be computed with the Cronbanch's Alpha which is used to measure the internal consistency of the instrument or access. The Cronbach's Alpha splits all the questions in the instrument in every possible way and it computes the correlation value for these questions. The generated number for the Cronbach's Alpha is just like a correlation coefficient; the closer it is to 'one', the higher the reliability estimate of the instrument. According to Sekaran (2000), in a reliability analysis where the value of the Cronbach's Alpha is less than 0.6, the outcome is considered as poor; a value of more than 0.7 is considered as acceptable and a value of more than 0.8 is considered as good. Six respondents participated in the pilot study. Based on the feedback given, modifications were made to the questions.

f. Delphi Survey Process

Two rounds of Delphi survey were conducted in this study. The survey process is illustrated in Figure 3.2.

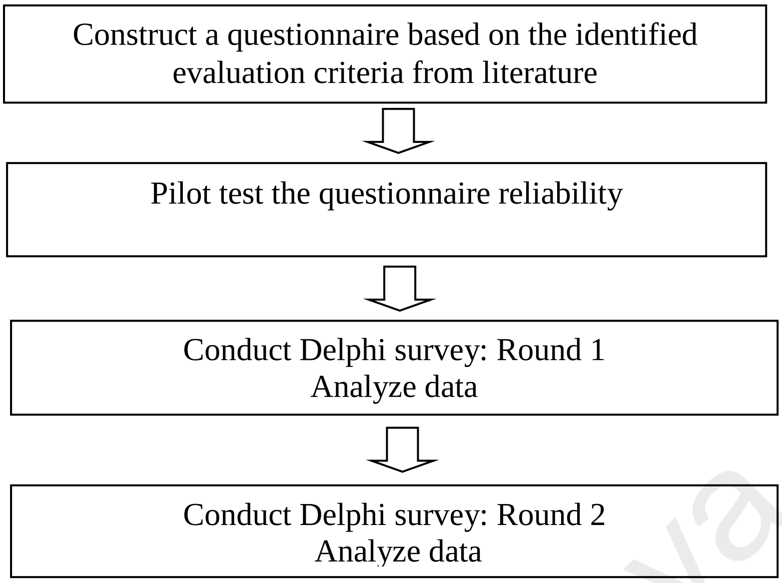


Figure 3.2: Processes in Delphi Survey

i. Conducting Round 1 of the Delphi Survey

The questionnaire was given or emailed to the 31 experts comprising Technical Experts, Decision Makers and Academicians/Researchers. Initially, 100 experts were successfully contacted through the email and phone calls and 50 agreed to participate. However, only 31 experts participated consistently in Round 1 and Round 2. Out of the 31 experts, majority of them had been involved in the preliminary survey. The experts were requested to rank the shortlisted evaluation criteria and sub-criteria. They were also asked to suggest additional criteria that may be important, based on their preference. From this survey, the expert's consensus of the evaluation criteria and sub-criteria were obtained.

ii. Conducting Round 2 of the Delphi Survey

The basis for each round of Delphi survey is the aggregated information gathered from the previous round (Skulmoski et al., 2007). In this study, the questionnaire for Round 2 survey was constructed based on the results of Round 1, consisting of the existing literature-based criteria and those added by the experts in Round 1. The same experts who participated in Round 1 were also involved in Round 2. They were asked to rank both the literature based criteria and the newly added evaluation criteria. Similar to Round 1, they were also invited to provide additional criteria that may be important, based on their preference. The questionnaire for Round 2 of the Delphi survey is included in Appendix C. The results of Round 1 and Round 2 of the Delphi survey are also presented in Tables 5.6 - 5.16 in Chapter 5.

iii. Data Analysis Used in Delphi Survey

The Descriptive statistics drawn from the SPSS version 15.0 were used to analyse the data obtained from the Delphi survey. The Inter Quartile Range (IQR) and the Median scores were analyzed to determine the level of consensus obtained from the experts (Murry & Hammons, 1995). The IQR was conducted so as to identify the relationship between each of the item or the experts concerned (Zakaria et al., 2015).

The identification of the relationship will determine the interpretation of the consensus for each item noted in the Delphi method. The items in this study are the e-LS evaluation criteria. The analysis of the IQR depends on the Likert scale used in the questionnaire. In this study, a 5-point Likert scale was used and the IQR is reported as follows:

An $IQR = 0$ can be considered as a high consensus, as it is the highest level achievable. An $IQR = 1$ can be considered as a good consensus. An $IQR = 2$ can be considered as a moderate consensus (Linston & Turoff, 1975; Vandelanottee et al., 2010; Jünger et al., 2012). An $IQR > 2.0$ can be considered as without consensus and this indicate that there is a disagreement between the experts on their ratings (Kupec, 2013).

In this study, the Median score shows the result of the experts' consensus on the relevance or importance of each criterion (Vandelanottee et. al, 2010). The Median score was also examined to consider whether the evaluation criteria should be accepted or rejected by a majority of experts (Zakaria et al., 2015; Ononiwu, 2013; Pichlak, 2015).

On a 5-point Likert scale, the evaluation criteria with a Median score of less then 3.5 indicates a low consensus among experts. This would be rejected accordingly (Ononiwu, 2013; Pichlak, 2015).

Mean, Standard Deviations, Mean Average and Standard Deviations Average have been used in many Delphi studies including the information system studies, to determine the priority of the criteria or the items (Decleva & Zupančič, 1996; Clark, 2006; Lai, 2001). In this study, the mean Average and Standard Deviations Average were also analysed in order to determine the priority of the evaluation criteria for the e-LS. The criterion with the higher mean average is considered important, based on the experts' view.

After the Round 2 analysis, the e-LS evaluation criteria from the experts consensus were listed according to the sequence of importance based on priority. The results are discussed in Section 5.3.4.

The criteria and sub-criteria identified from the literature, the ISO/IEC9126-1 Quality Model, the ISO/IEC 25010, the COTS framework and the Delphi survey were then compiled in preparation to construct the ISQM for the e-LS.

3.3.2 Formulation of the ISQM-Fuzzy AHP Evaluation Framework for e-LS

Results drawn from the literature review and the preliminary survey have indicated that there was a current lack of guideline to be used in the evaluation of the e-LS by organizations. To overcome this lack, the ISQM-Fuzzy AHP evaluation framework was formulated as a measure to support organizations in the evaluation process of the e-LS. The ISQM-Fuzzy AHP framework has been adapted at various stages of the COTS based process (Ruhe, 2003). The COTS based process was discussed in section 2.5.2, with some amendments using the Fuzzy AHP technique. This was then consolidated as a tool. The criteria and sub-criteria of the ISQM are stored in the tool database. The ISQM-Fuzzy AHP framework consist of 6 stages: i. Requirement identification; ii. User management; iii. Model Construction; iv. Evaluation; v. Viewing of results and vi. Selection Process of the e-LS. The evaluation process applies the Fuzzy AHP technique in the proposed framework. A detailed explanation about the formulation of the ISQM-Fuzzy AHP evaluation framework for the e-LS evaluation can be found in Section 5.6.

As mentioned in Chapter 2, numerous approaches can be used for the Fuzzy AHP technique proposed. In the context of this study, the Fuzzy AHP technique developed by Chang (1996) was adopted. Chapter 7 will explain Chang's (1996) Fuzzy AHP technique which consists of a systematic approach that is made up of alternative selections which use the concept of fuzzy sets theory and hierarchical structure analysis (Kahraman, et al., 2003). Chang's (1996) Fuzzy AHP technique was further refined and used in the ISQM-Fuzzy AHP evaluation framework. A tool will also be developed based on the ISQM-Fuzzy AHP evaluation framework as a means to assist organizations in the evaluation process of the e-LS. The formulation of the e-LS evaluation framework will be discussed in Section 5.5.

3.3.3 Software Tools for Data Analysis in Phase 2

The Microsoft Excel 2010 and the SPSS version 15.0 were used in the data analysis. The former was used to tabulate the criteria identified and collected from literature while the latter was used to analyse the consensus and priority of the criteria and sub-criteria, among the experts.

3.4 Phase 3: Development of a Tool (e-LSO) Based on the ISQM-Fuzzy AHP Evaluation Framework

Phase 3 elaborated the development of a tool that was derived from the ISQM-Fuzzy AHP evaluation framework for e-LS evaluation. The evaluation criteria and the sub-criteria that were identified added to the list of criteria and this subsequently, validated the Delphi survey that was used to construct the ISQM for the evaluation of the e-LS. The ISQM will be described in Section 5.4. It integrates all important evaluation criteria and the sub-criteria that have been validated by experts. These will be used in the evaluation process of the e-LS. In this study, the e-LSO would be developed as part of the e-LS evaluation framework so as to support the evaluation process of the e-LS. The steps involved in the development of the e-LSO using prototyping approaches are explained in Chapter 5. The following section will discuss the e-LSO development and the processes involved for the evaluation of the e-LSO. Elaborations of this are in Chapter 6.

3.4.1 e-Learning Software Option (e-LSO) Tool Development

Results from the preliminary survey have shown that there was a need for a tool to assist in the evaluation process of the e-LS. The preliminary survey had indicated that majority of the experts did not use any specific tool for the evaluation of the e-LS. Moreover, the evaluation process varied from one expert to another. There was no specific process that organizations had to abide by for evaluating the e-LS. Some experts had indicated that their organizations used spreadsheet forms and general decision tools such as Expert Choice in their evaluation process. However, these tools did not provide the users with any selected criteria and sub-criteria that can assist fully in the evaluation process of the e-LS. The preliminary survey also revealed that majority of the experts agreed with the availability of a support tool that can assist in the evaluation and selection of the e-LS. As mentioned in Section 2.8, very few tools have been introduced in the e-LS evaluation process. Moreover, the evaluation criteria provided in the current existing tool is not sufficient enough to support the evaluation of the e-LS.

The current criteria used in the evaluation phase focused on readily available LMS only and these criteria are also based on general features which may not be adequate for certain specific e-LS products. An adequate tool should be able to provide a list of comprehensive criteria which can be used to support many types of e-LS evaluations, as discussed in chapter 2. Similar to the other software products, the evaluation of the e-LS is a complex process which may be complicated as well as time consuming. In this regard, a support tool that uses appropriate techniques as well as facilitates the e-LS evaluation process is imperative as technology advances and more and more software are being rapidly developed. In the context of this study, the e-LSO tool was developed. The suggested e-LS evaluation framework for e-LS evaluation will be used in the e-LSO. This was discussed in Section 3.3.3. The Fuzzy AHP technique was proposed for use in the evaluation process of the e-LS while the e-LSO would include a number of necessary criteria and other sub-criteria which have been extracted from the ISQM. e-LS alternative obtained from the preliminary survey conducted in Malaysia are stored in the e-LSO database. With an adequate framework, organizations can create their own decision model in the evaluation process of the e-LS, based on their respective needs. As explained in Section 2.7, the Fuzzy AHP technique is good but it is a complex task if calculations are conducted manually. An appropriate e-LSO could facilitate the evaluation process; it could automatically calculate the complexities of the mathematical formula of the Fuzzy AHP technique and it would enable organizations to save time. The following section discusses the process involved in the proposed e-LSO.

3.4.2 Processes in e-LSO

This section briefly discusses the process involved in the e-LSO which can enable users to create their own decision models when evaluating the e-LS product. The process involved in the e-LSO consists of:

a. Process 1: Goal Definition Process

In this process, the goal and requirements are defined in order to allow the users to define a new goal for the e-LS evaluation, based on user requirements

b. Process 2: Model Definition Process

In this process, the evaluation criteria, the sub-criteria and the e-LS alternatives are defined. The users may select the available criteria, sub-criteria and the e-LS to create their own decision model.

c. Process 3: Evaluation Process

This process contains two steps.

i. Define Model Process

First, this process allows the users to define their decision model. The e-LSO offers users with a set of evaluation criteria, sub-criteria and the e-LS. In addition, it also allows the users to add other criteria, sub-criteria and e-LS based on user needs. A Fuzzy AHP decision model consisting of the defined goal, evaluation criteria and sub-criteria as well as the e-LS alternatives may also be created for the evaluation purposes.

ii. Pairwise Comparison Judgment Process

Next, the e-LSO offers options to the users as a means to enable users to establish metrics based on the criteria, sub-criteria and alternatives selected. Subsequent to this, the e-LSO also provides users with options such as:

- perform pairwise comparison judgments of the selected criteria over another criteria; the e-LSO can also calculate the respective criteria weights
- perform pairwise comparison judgments of the selected sub-criteria over another sub-criteria and the e-LSO can also calculate the respective sub-criteria weights
- perform pairwise comparison judgments of the e-LS alternative over another e-LS software with respect to each sub-criterion; the e-LSO can also calculate the respective e-LS weights

d. Process 4: Analyzing Result Processes

Based on the evaluation calculated, the e-LSO can also be used to analyse the results taken from the pairwise comparison judgments. The overall result can then be viewed based on the e-LS priority. The users can use the results to make an appropriate decision so as to select the most suitable e-LS. The processes involved in the e-LSO are further explained in detail in Section 5.5.

3.4.3 Development of e-LSO Using Evolutionary Approaches

The tool that is developed in this study will be used in the proposed e-LS evaluation framework as a means to assist in the e-LS evaluation process. In the realm of system development, various methodologies are used for software development such as evolutionary prototype, System Analysis and Design Method (SSADM), Rapid Application Development (RAD), Waterfall and Agile. In this study, the prototype approach was adopted because:

- It is a robust method to realize the requirement of some aspects of a system (Köksalan et al., 2011);
- It is highly reliable as it involves users in the analysis and design which captures the requirements in a concrete form (Kabir & Hasin, 2011).

Thus, the e-LSO would be constructed using the evolutionary prototype approach. The development of the e-LSO would be further described in Chapter 6. The development process consists of five steps which include: requirement, design, build prototype, testing and implementation. This is projected in Figure 3.3.

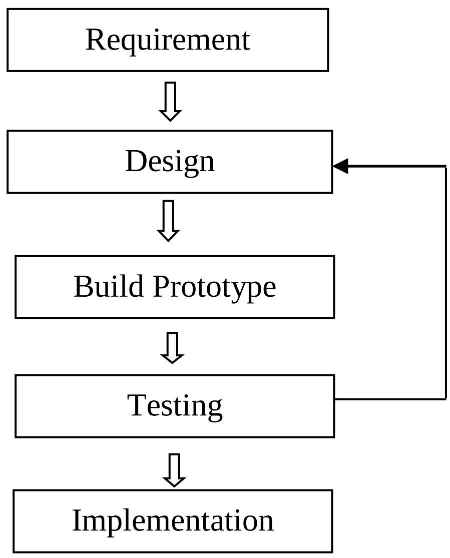


Figure 3.3: Five Steps in the Development of the e-LSO Using Evolutionary Prototyping Approach

The evolutionary prototyping approaches assumes that the construction of a particular prototyping system follows an incremental or step-by-step, process. The evolutionary prototyping approach enables users to have an actual feel for the usage of the tool. The interactions with the tool would enable a better understanding of its requirements.

3.4.3.1 Requirement

In order to develop a good Internet based system, it is very important to choose the appropriate hardware, software and technology. The hardware and software used to develop the e-LSO are described below:

a. Software Requirement

This section discusses the programming tools, user interface tool, database technology, and server technology which are used to develop the e-LSO. In this study, the PHP programming tool, Adobe Dreamweaver, MySQL 5.1 and Apache web server were used to construct and implement the e-LSO for this study.

Programming Tool. The PHP version 5.3.25 was selected as the programming tool for the development of the e-LSO. It was chosen as the development platform because it is a comprehensive and easy to learn package for the development of dynamic websites.

User Interface Design Tool. The Adobe Dreamweaver was selected as the software for the development of the interface design tool. The software would be used as the tag editor for the PHP programming, and it will also facilitate the programming process. The Dreamweaver is an environment that provides a visual interface which can identify programs as web services. It was chosen as the design tool because it provided the platform to build user interface; it also provides features that can be used to integrate the existing application data and it can also be used for program debugging. Most importantly, it was able to support the PHP framework that facilitated the application development for the web services.

Database Tool. MySQL 5.1.66 was used as the Database Management System (DBMS) for the e-LSO. It was chosen due to its open source database server that was based on the Structured Query Language (SQL) that has a full-featured database management system. It is popular for web applications and it can act as the database component. Furthermore, it is able to work on many different system platforms. It also provides a stable and reliable platform for data storage, thus allowing the administrator to view/monitor all the MySQL server monitoring related events from a centralized console. The MySQL also offers exceptional security features which can ensure absolute data protection by providing powerful mechanisms that can ensure that only authorized users have access to the database server.

Web Server. The Apache was chosen as the web server for the e-LSO because it has been one of the most popular web servers on the Internet since April 1996. It is a public-domain open source web server that is developed by a loosely-connected group of programmers. In this study, the Apache 2.2.24 was chosen because it is currently considered to be the best version of the Apache available.

b. Hardware Requirement

The following hardware were chosen for the installation and running of the e-LSO, in a web based environment. The requirements considered both the server and the clients' sites.

Server

- Processor: Processor Core 2 Duo 1.86GHz or Higher
- RAM: 2 Gigabyte
- Network Card: 10/100 Mb Network Card

Clients

- Processor: Pentium 4, Intel Core or Higher.
- RAM: 1MB (minimum)
- Network Card: 10/100 Mb Network Card

3.4.4.2 Design

In this study, the e-LSO design comprised the flow chart, context diagram, Data Flow Diagram (DFD) and the Interface design. The physical design of the system focuses on the system specifications (Omar et al., 2011).

3.4.3.3 Build Prototype

As proposed in the design phase, the e-LSO was constructed to consist of several modules. The e-LSO modules will be translated to the user interface which then enables the interaction between the user and the system to occur. The interface was designed based on the proposed module and the design of the system.

3.4.3.4 Testing

The testing process involved the actual use of the completed system. The testing of the entire system, also known as system testing, would be able to highlight any defects and weaknesses noted in the system (Satzinger, et. al., 2011). In the context of this study, testing was performed for each module that was developed as a means to ensure that each module was free from errors and the system fulfiled the users' requirements.

In the evaluation session of this study, the experts were required to test the e-LSO. The testing involved the unit testing and the acceptance testing of the e-LSO. The experts involved were invited to participate in the testing phase. Their feedback was then used to improve the system. As the e-LSO was developed under a web based environment, the first testing was conducted at the local host and the second testing was conducted on the server hosting the e-LSO.

a. Unit Testing

Unit testing, also known as module testing, involves the testing of each individual module. The aim is to identify any possible errors in the module code (Hoffer et al., 2011). Unit testing will test the components of the individual module independently. Following the unit testing, a system testing, which tested the e-LSO as a whole, was then conducted once.

b. Acceptance Testing

The purpose of the acceptance testing for the e-LSO was to determine whether it is able to meet the users' requirements. Acceptance refers to the fact that users typically sign off on the system and accept it (Hoffer et al., 2011). The e-LSO developed in this study would be the second version (Version 2.0) after improvements were made on the first version (1.0), based on feedback obtained from the users at the testing phase.

3.4.3.5 Implementation

Upon acceptance, the e-LSO will then be implemented in a web based environment so as to allow users access via the Internet.

3.5 Phase 4: Evaluation of e-LSO

In this phase, the usability evaluation of the e-LSO was conducted. The evaluation provides feedback that can be used as additional information to better understand any problem that exits. This information can then be used to improve both the quality of the product and the design process (Von Alan et al., 2004). The design process is a sequence of expert activities that can help to produce innovative products such as the e-LSO. The following section describes the construction of the usability questionnaire based on PSSUQ, the selection of the experts and the procedures highlighting the evaluation of its usability.

3.5.1 PSSUQ Questionnaire Construction

The usability evaluation adopts the approach used by Jadhav and Sonar (2011). The usability question noted for the e-LSO evaluation was adapted from a renowned source, namely, the Post-Study System Usability Questionnaire (PSSUQ) (Ravichandran & Rothenberger, 2003). In this study, the PSSUQ was constructed based on the IBM Computer System Usability Questionnaire (CSUQ) with several exceptions (Triantaphyllou, 1995) and some minor changes made in the wording (Chang, 1996). The PSSUQ attributes can be seen in Lewis (1995) and Lewis (2002). The CSUQ was designed for it to be administered via email or online whereas the PSSUQ was constructed for it to be administered face-to-face among individuals (Chang, 1996). The PSSUQ was adopted for this study because of the need to conduct the survey in person with the experts. The PSSUQ is a 19-item instrument (Tang & Beynon, 2005).The items of the PSSUQ are categorised into four groups namely: usefulness, information quality, interface quality and the overall system satisfaction (Chang, 1996).

i. System Usefulness: The degree to which a person believes that using a particular system would enhance his/her job performance (Davis, 1989)

ii. Information Quality: Information quality refers to the quality of output the information system produces (DeLone & McLean, 1992); it can be in the form of reports or online screens.

iii. Interface Quality: The interface quality includes those items used to interact with the system. For example, the components of the interface are the screen including the use of graphic and language.

iv. Overall Satisfaction: The deficiencies of questionnaires can be addressed by the establishment of a context of use, the characterization of the end user population, and the understanding of tasks for the system to be evaluated (van Veenendaal, 1998; Ricchi & Nguyen, 2007).

In this study, the modification was made by adapting the PSSUQ to develop a more specific questionnaire which is tailored to suit a particular research interest. For example, the PSSUQ was adapted and modified to test the usability evaluation and to verify the functionality, efficiency, effectiveness and convenience of the mobile phone recommender system (Ricchi & Nguyen, 2007). The PSSUQ was also used in the evaluation of other software products (Jadhav & Sonar, 2011). The present study will adopt the PSSUQ questionnaire as a means to conduct the usability evaluation of the e-LSO.

The items in the survey were also categorized into four categories. This is shown in Table 3.1. It comprises the Overall satisfaction component (items 1-20), the System usefulness (items 1-8), Information Quality (items 9-15), and the Interface Quality (items 16-18). These items were categorized into the e-LSO usefulness, the e-LSO information quality and the e-LSO interface quality. Items 1-14 were created and grouped under the category of e-LSO usefulness. Items 15-17 were grouped under the e-LSO Information quality. Items 18-20 were grouped under the e-LSO Interface quality and Item 21 was categorized under the overall satisfaction. In evaluating the e-LSO, attributes drawn from the PSSUQ were adapted. This is achieved by changing several sentences and wordings in the construction of the questionnaire. It involved items 17, 18, 19 and 21. For each item noted in the e-LS usability questionnaire, the word "system" in the PSSUQ was changed to "e-LSO".

All the 21 items were then used to construct the usability questionnaire. The content of the questionnaire was divided into 3 sections as listed in Appendix F. Section A of the questionnaire required the selected experts to fill in their demographic information. Section B of the questionnaire required the experts to evaluate the usability of the e-LSO. Table 3.1 defines each of the items used in Section B of the usability questionnaire.

Table 3.1: Items for the e-LSO Usability Evaluation

No	Statements about e-LSO	Scale						
1.	I can specify the evaluation goal according to my requirements	1	2	3	4	5	6	7
2.	I can select the evaluation criteria and sub-criteria according to my requirements	1	2	3	4	5	6	7
3.	I can add other evaluation criteria and sub-criteria according to my requirements	1	2	3	4	5	6	7
4.	The criteria, sub-criteria and e-Learning software alternatives for evaluation are readily provided in e-LSO tool	1	2	3	4	5	6	7
5.	The evaluation criteria and sub-criteria are suitable for e-Learning software evaluation	1	2	3	4	5	6	7
6.	The criteria and sub-criteria provided are comprehensive and adequate for e-Learning software evaluation	1	2	3	4	5	6	7
7.	I can select e-Learning software alternatives for evaluation	1	2	3	4	5	6	7
8.	I can add other e-Learning software alternatives for evaluation	1	2	3	4	5	6	7
9.	It is easy to select the evaluation criteria, sub-criteria and e-Learning software for evaluation	1	2	3	4	5	6	7
10.	It is easy to do pairwise comparison and rank each criteria, sub-criteria and e-learning software alternative with e-LSO tool	1	2	3	4	5	6	7
11.	The scale provided to rank the evaluation criteria, sub-criteria and e-Learning software alternatives minimize uncertainty in my judgement	1	2	3	4	5	6	7
12.	I can quickly complete the evaluation process with e-LSO tool	1	2	3	4	5	6	7
13.	e-LSO tool is useful in the evaluation and selection of e-Learning software	1	2	3	4	5	6	7
14.	It was easy learn to use e-LSO tool	1	2	3	4	5	6	7
15	e-LSO tool show me mistakes that I have made in the pairwise comparison judgment on the criteria, sub-criteria and e-Learning software	1	2	3	4	5	6	7
16.	The evaluation result is easily understood	1	2	3	4	5	6	7
17.	I am confident with the result to assist me in the selection of e-Learning software	1	2	3	4	5	6	7
18	The interface is pleasant	1	2	3	4	5	6	7
19.	The interface is easy to navigate	1	2	3	4	5	6	7
20.	e-LSO tool has all the functions and capabilities I expect it to have	1	2	3	4	5	6	7
21.	Overall, I am satisfied with e-LSO tool	1	2	3	4	5	6	7

Section C of the questionnaire comprised interview questions which expect the experts to answer several questions upon completing the evaluation phase and upon filling in the usability questionnaire.

3.5.2 Respondents in Usability Evaluation

The usability evaluation only required three to five domain experts to test the particular system (Nielson, 2000). Liaw (2008) emphasised that usability evaluation could produce the best result from the usability testing if not more than five experts participated at one particular time. The usability evaluation has been used to solve problems in software selection, as mentioned by Jadhav and Sonar (2011) and in the context of this study, only three respondents were involved. As the three (3) respondents were experts, the usability testing of the software was considered sufficient for validation. In this study, the seven experts selected were made up of two participants who participated in the pilot study and five participants who were involved with the usability test. The experts were contacted via email or through telephones. These five experts were new respondents who had not participated in both the preliminary survey and the Delphi survey phases. The selection and detail of the experts are described in Chapter 7.

3.5.3 Usability Evaluation Procedure

The usability evaluation of the e-LSO was conducted on a one-to-one basis. The five experts who agreed to take part in the e-LSO usability evaluation were given an email of the time and date for conducting the evaluation. The experts who participated in the usability evaluation were those who were directly involved in the implementation of e-learning in their respective organizations. The usability evaluation was administered in the following procedure:

3.5.3.1 Interview Before Using e-LSO

Prior to introducing the experts to the e-LSO, they were first interviewed about their current practices noted in the e-LS evaluation and selection process. The interview questions are included in Appendix G.

3.5.3.2 Evaluation of e-LSO

The evaluation of the e-LSO was conducted in 2 stages, as discussed by Ricci and Nguyen (2007) and Jadhav and Sonar (2011). They include: i. experts were trained to use the e-LSO; and ii. experts used the e-LSO to evaluate the e-LS.

a. Train Experts Using e-LSO

In this stage, the experts were trained on how to use the e-LSO. In the training session, experts were given the e-LSO user manual. This is shown in Appendix J. The purpose of the manual was to assist the experts in understanding the e-LSO. It was also to ensure that the experts have a general understanding of the flow, the e-LSO functions and how the e-LSO could assist them in choosing the evaluation criteria for evaluating the e-LS. The one-to-one training which took approximately 15 minutes, was conducted in the experts' office, at their respective organizations.

b. Experts Use e-LSO to Evaluate the e-LS

Once the experts have familiarized themselves with the e-LSO, they were requested to use the system to evaluate the e-LS, based on their requirements. The usability questionnaire was answered on a seven point Likert scale, with values ranging from 1 (strongly agree) to 7 (strongly disagree) (Appendix H).

3.5.3.3 Interview After Using e-LSO

In an interview session after the experts had filled the usability questionnaire, they were also required to answer several questions. This question is shown in Appendix I. The experts were also asked on how they specify their goals and their requirements in the evaluation of the e-LS as well as their reasons for choosing the evaluation criteria, sub-criteria and the software alternatives. The experts were also asked to provide their opinions about the current method of evaluating and selecting the e-LS compared with just using the e-LSO. At the end of the session, they were also asked to specify the strength of the e-LSO; the weakness of the e-LSO; and the improvement that can be made on the e-LSO to overcome the weaknesses.

3.5.4 Software Tools and Data Analysis in Phase 4

The analysis of the descriptive statistics derived from the SPSS version 15.0 was used to evaluate the usability of the e-LSO.

The data analysis in the evaluation phase was divided into two parts:

a. Analysis of the Pairwise Comparison Results

The results of the pairwise comparison of the selected evaluation criteria, the sub-criteria and the e-LS alternatives were analysed. The relative weight of each evaluation criterion was calculated by the e-LSO. A weight is the degree of relative importance amongst the elements (Haq & Kannan, 2006). Triangular fuzzy numbers were used to represent the experts' preferences in the pairwise comparison judgment of the selected criteria, sub-criteria and the e-LS alternatives, through linguistic terms. The weight vectors were then calculated and the normalized weight vectors were determined. The experts' pairwise comparison results are presented in Chapter 7.

b. Analysis of the Usability Evaluation Results

The result of the usability evaluation was analysed based on the mean average, as suggested by several researchers (Lewis, 2002; Ricchi & Nguyen 2007; Jadhav & Sonar, 2011). Descriptive statistics were used to analyze the usability result of the e-LSO. The usability results of the e-LSO are also presented in Chapter 7.

Table 3.2 summarizes the methods used in each of the four phases. This chapter has also discussed the objectives of the study, the instruments developed, how data were collected and the sampling number. This chapter ends with the chapters that will reveal the results.

Table 3.2: Summary of Data Collection Methods

Duration	Objective	Method/ Instrument	Data collected	Samples	Results
One year	-Investigated the current practice in the evaluation and selection of e-LS	Questionnaire	Existing practice on e-Learning software evaluation and selection in the context of Malaysia	50 experts	Chapter 4
6 months	-Formulated ISQM for e-LS evaluation -To select e-LS evaluation criteria from literature review	Literature Review	e-Learning software evaluation criteria	50 related articles	Chapter 5
4 months	-Identified the e-LS criteria based on expert agreement	Delphi Survey /Questionnaire Round 1	-Demographic information -criteria added by experts - criteria priority based on 5 Point Likert Scale	31experts	Chapter 5
4 months	- Obtained consensus among experts	Delphi Survey/ Questionnaire Round 2	-Revised criteria priority based on 5 Point Lickert Scale	31experts	Chapter 5
7 months	- Developed a tool, e-LSO, using evolutionary prototyping approaches	Evolutionary Prototyping approaches	-	-	-
1 month	-Evaluated the usability of e-LSO tool	PSSUQ Questionnaire	- Usability survey data	5 experts	Chapter 7

3.6 Summary

This chapter has presented the overall research methodology carried out in this study. The research methodology consist of four phases involving the identification of the research problem; the construction of the ISQM and the formulation of the ISQM-Fuzzy AHP evaluation framework for the e-LS evaluation. it also discussed the development of a tool (e-LSO) based on the ISQM-Fuzzy AHP evaluation framework as well as the evaluation of the usability of the e-LSO. In addition, the methods derived from literature review linked to the purpose of the preliminary survey were also described. The literature review and the Delphi survey used to identify and validate the e-LS evaluation criteria were also explained. The proposed methods for developing the ISQM and the ISQM-Fuzzy AHP framework for the e-LS evaluation were also introduced briefly. Finally, the development and the usability evaluation of the e-LSO were also mentioned.

CHAPTER 4: CURRENT PRACTICES IN THE EVALUATION AND SELECTION PROCESS OF E-LEARNING SOFTWARE

4.1 Introduction

The first step of the research process was in identifying the research problem as explained in Section 3.2. The research problem was determined from the literature review and the preliminary survey that was administered on a group of experts who were made up of Technical Experts, Decision Makers and Academicians/Researchers. The objective of the preliminary survey was to collect information about the current practices noted in the evaluation and selection process of the e-Learning Software by organizations when implementing e-Learning in the context of Malaysia. The information obtained from the preliminary survey aims to answer Research Question One:

What are the limitations in the current practices of the evaluation and selection of the e-LS?

In chapter 3, Section 3.2.2 already described the details of the preliminary survey. It also mentioned the profile of the experts, the construction of the questionnaire and the procedures taken to administer the survey and to collect data for analysis. The results of the preliminary survey are presented in this chapter. It begins by looking at the demographic results obtained from the preliminary survey. This is followed by a report (Section 4.3) about the current practices of the evaluation and selection of the e-LS by organizations in Malaysia**.**

4.2 Demographic Results of the Preliminary Survey

The demographic results drawn from the preliminary survey include information revealing the experts' background such as the types of organization they come from, their expertise based on the category of their job functions, educational attainments and the length of their working experience in years. These demographic results will also be used to verify the qualifications of the experts and therefore, their expertise and validity of their responses. Table 4.1 illustrates the demographic results.

Table 4.1: Demographic Background of Experts

Items	**Frequency**	**Percentage**
Types of Organization		
University/College	39	78%
Semi Government / Public Sector	5	10%
Private Sector	3	6%
Developer / Vendor	3	6%
Experts Category Based on Job Function		
Technical Experts: Software developer, System Engineer, Analyst Programmer, Programmer	18	36%
Decision Maker: Director of Information Technology(IT), IT Manager	12	24%
Academician/Researchers: Academic practitioner and researcher	20	40%
Educational Attainment		
PhD 's	13	26%
Master's	22	44%
Bachelor's	12	24%
Diploma's	3	6%
Years of Working Experience		
Less than 5 years	4	8%
6 – 10 years	15	30%
11 -15 years	23	46%
16 – 20 years	4	8%
More than 20 years	4	8%
Total	**N=50**	**100%**

a. Type of Organization

The experts were based in various established organizations in Malaysia such as universities/colleges, public and private sectors as well as software companies. Out of the 50 experts, 78% were university personnel, 10% worked in semi government offices, 6% from private sectors and 6% worked in software companies. Based on the preliminary survey results, the majority of the experts were from educational institutions. The types of organization are illustrated in Figure 4.1.

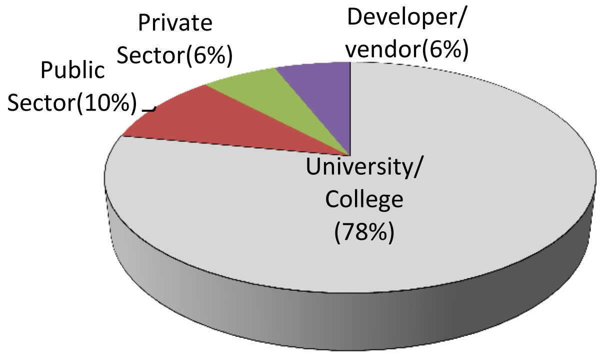


Figure 4.1: Types of Organizations.

b. Experts Category Based on Job Functions

The experts were categorized based on their job functions where 36% were Technical Experts, 24% were Decision Makers and 40% were Academicians/Researchers who were directly involved in the implementation of e-Learning in their organizations. The experts' category based on the job function is shown in Figure 4.2.

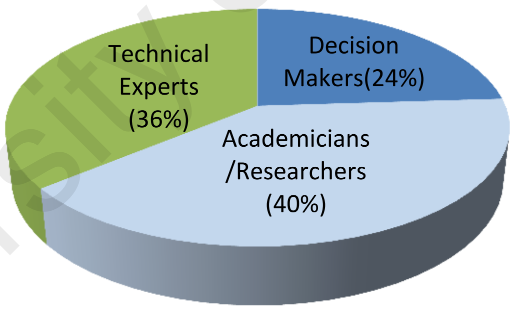


Figure 4.2: Experts' Category Based on Job Function

c. Educational Attainment

Experts were selected based on their academic qualifications which varied from diploma to PhD graduates. It was shown in the results that 26% experts were PhD holders, 44% experts have Master's degree, 24% experts obtained Bachelor Degree and 6% experts have Diploma. The educational attainment of the experts is shown in Figure 4.3.

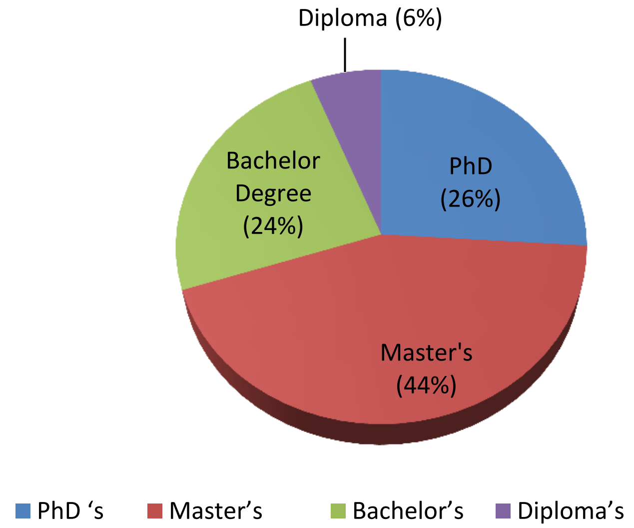


Figure 4.3: The Educational Attainment of Experts.

d. Working Experiences

Although the survey showed that 8% of the experts have less than five (5) years of working experience, they were in fact, full time researchers who were directly involved in the area of e-learning. Based on their research involvement, they were invited to participate in the survey. From the outcome of the survey conducted, it was noted that 30% of the experts have 6-10 years of working experience, 46% of the experts have 11-15 years of working experience, 8% of the experts have 16-20 years of working experience and only 8% of the experts have more than 20 years of working experience. Based on this, it can be deduced that majority of the experts have more than 10 years of working experience, hence their knowledge and experience in the e-Learning component should be acceptable. The outcome of their profile is illustrated in Figure 4.4.

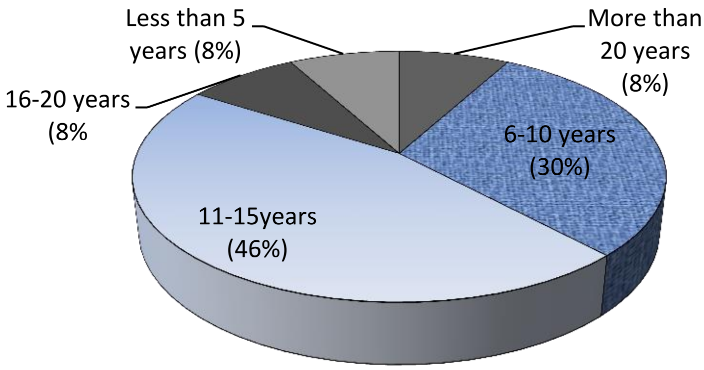


Figure 4.4: Experts' Years of Experience

As can be seen, the demographic results showed that the respondents were indeed experts consisting of Technical Experts, Decision Makers and Academicians/Researchers who were from various organizations that had made the choice to implement e-Learning within their organizations. These experts were selected based on their broad knowledge in e-Learning as can be verified by their years of working experiences and their qualifications. It was obvious that majority or 92% of these experts have more than five years of working experience and 94% of them held a Bachelor's Degree in qualification. These information helped to ensure the credibility of the experts and therefore, the validity of their consensus when suggesting quality criteria for the development of a new evaluation model that consists of a sequence of processes which can be used by organizations to evaluate the e-LS that would be implemented by the organizations.

4.3 Current Practices of the Evaluation and Selection of the e-LS in Malaysia

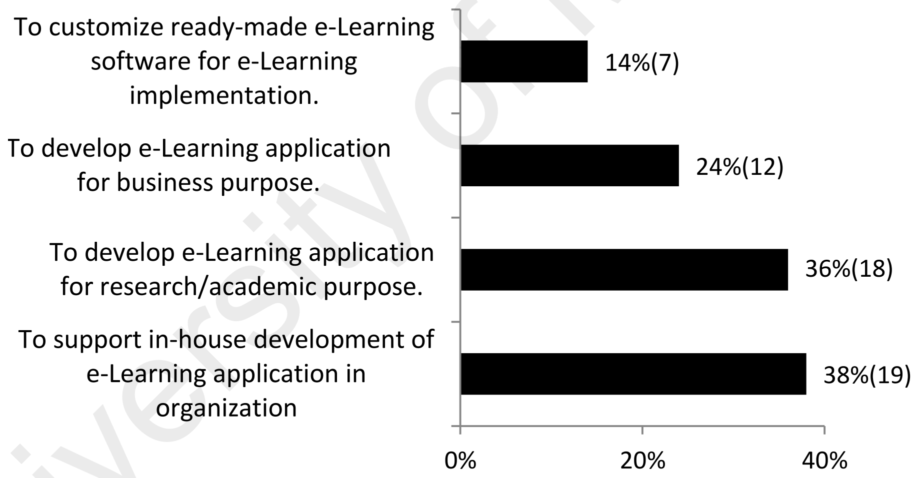
The results obtained for each of the five areas of interest are presented in this section. The five areas covered in the survey include the implementation of e-Learning, stages and methods in the evaluation and selection process, identification of the evaluation criteria, support tools used and problems encountered in the evaluation and selection process.

4.3.1 The Implementation of e-Learning

a. The Purpose of Organizations Using the e-LS

The preliminary survey had revealed the purpose of organizations in implementing the e-Learning and using the e-LS. From a total of 50 experts surveyed, 38% of them used the e-LS to support their in-house development; 36% of them used the e-LS for academic/research purposes; 24% of them used the e-LS to develop the e-Learning applications for business purposes while 14% of them customized a ready-made e-LS for e-Learning implementations within their organizations. The breakdown of the experts' purpose in using the e-LS is shown in Figure 4.5.

The Purpose of Using e-LS



Percentage

Figure 4.5: The Purpose of Using e-LS

There were three options opened to the experts for implementing e-Learning and they include the options of utilizing Off-the-shelf programs, relying on an outside vendor to produce the e-Learning materials and to innovate an in-house development for training their own staff (Shoniregun & Gray, 2003). The results of the preliminary survey revealed that the e-LS was used by the respective experts for four different purposes in implementing e-Learning. It appears that the experts involved were generally using the e-LS to support their in-house development; they were also using the e-LS to encourage more efforts in academic/research purposes. The experts were also using the e-LS to develop e-Learning applications for business purposes. Only a few experts chose to customize the ready-made e-LS or the ready-made applications provided by external vendors for e-Learning implementation. It was observed that these experts' organizations prefer to develop their own e-Learning applications.

b. Approaches that Organization Use to Implement e-Learning

From the survey conducted, four approaches were identified for implementing the e-LS. Overall, 44% of the experts implemented e-Learning by developing the e-Learning application in- house; 32% of the experts cooperated with outside vendors to implement e-Learning while 28% of them purchased Off the Shelf or ready-made software products to implement e-Learning. A minuscule 4% implemented e-Learning by a direct procurement of e-Learning software from vendors. The breakdown on the approaches applied by the experts, thus organizations, to implement e-Learning is shown in Figure 4.6.

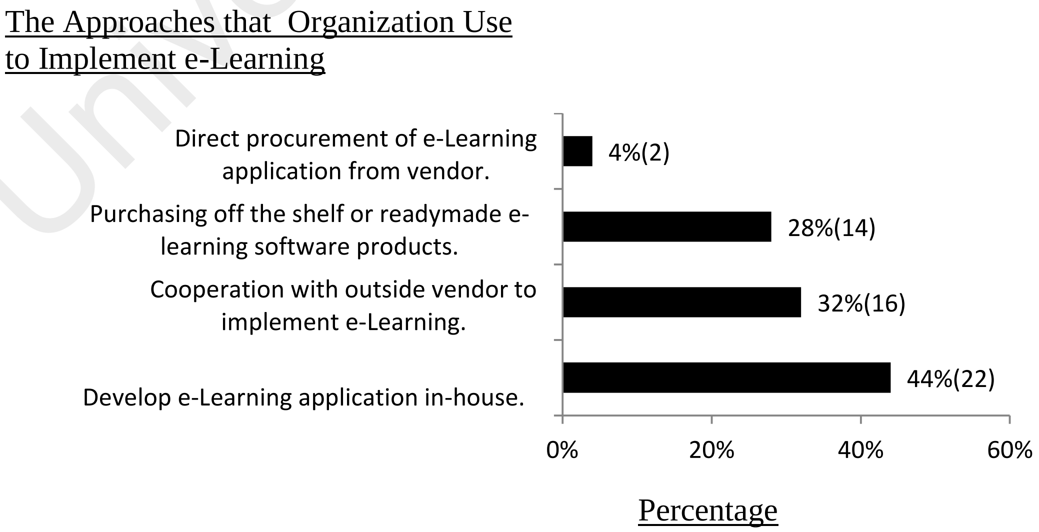


Figure 4.6: The Approaches that Organization Use to Implement e-Learning

Since there were many options to apply when implementing e-Learning, organizations may have to decide whether they want to utilize Off-The-Shelf e-Learning systems, rely on vendors to produce the e-Learning materials or to develop their own e-Learning system. Results from the survey showed that most of the experts prefer in-house development as compared to other approaches. However, it should be noted that building an in-house software system from scratch may incur increased investment cost and time (Suleiman, 2008). In-house development of the e-LS is a popular approach used by various organizations for implementing the e-Learning system. Undoubtedly, this approach offers the most freedom for organizations to develop their own e-Learning program materials (Shoniregun & Gray, 2003). In addition, it also allows for the development of some functions which are not readily available in commercial products such as the training program of a new product or services.

The organizations' preference for the in-house development approach may be attributed to the following reason. As the numbers of e-Learning products are developed through the in-house development approach, the organizations concerned can also increase the design and production of new products on their own. This process not only enhances their production level but also reduce operation costs of development. At the same time the process can also enable the organizations involved to consolidate their costs and so expenses can be kept to a minimal. Moreover, the in-house development approach also allows the respective organizations to have full control in the direction of their product development and the implementation of the e-Learning system. In contrast, organizations that rely on ready-made applications can only rely on vendors to create these products for their use. Alternatively, organizations may also order their software products from vendors who specialize in designing training materials for specific contents (Shoniregun & Gray, 2003). Nonetheless, both alternatives would cost the organizations more investment costs. This preliminary survey had noted that only a few organizations chose to rely on vendors to fulfil their organizations' needs by ordering their products from these vendors.

c. Types of e-LS that your organizations use to implement or develop e-Learning

It was found that both open source and commercial software were used by organizations in the implementation of e-Learning, as shown in Table 4.2.

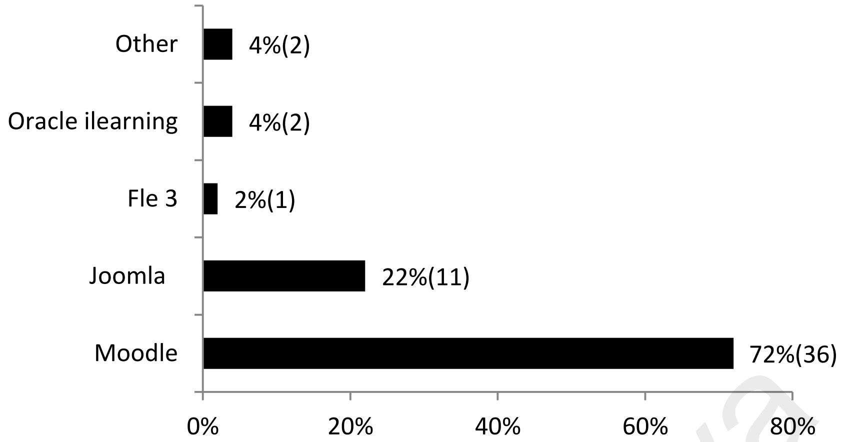
Table 4.2: Types of e-LS

Item		Frequency	Percent of Cases
Open Source	Moodle	36	72%
	Joomla	11	22%
	Fle3	1	2%
	Oracle i-learning	2	4%
Commercial	Blackboard	2	4%
	Webct	3	6%
	Web Learning	9	18%
	Lotus Learning Spaces	1	2%
	Other (i3learning solutions and Claroline)	2	4%
Total		67	134%

i. Open Source

Moodle was found to be the most popular open source software that organizations use in constructing e-Learning applications. It was shown from the result of the survey that 72% of the experts were using Moodle, 22% used Joomla, 2% used Fle 3 and only 4% used Oracle i-Learning for implementing the e-LS. The breakdown on the open source software used in the implementation of the e-LS is shown in Figure 4.7.

Open Source e-LS Providers



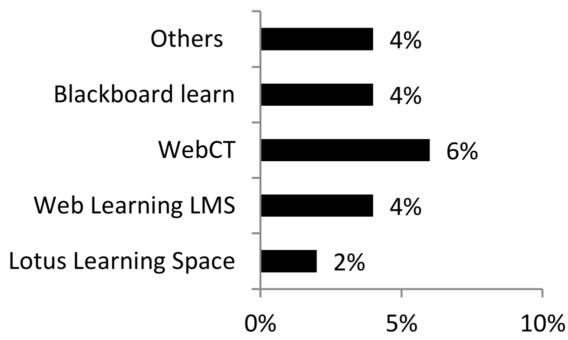
Percentage

Figure 4.7: Open Source e-LS Providers

ii. Commercial

For the experts that chose commercial software, 6% (3) of the experts were using Web CT, followed by 4% (2) who were using Web Learning LMS, 4% (2) were using Blackboard, and 2% (1) were using Lotus Learning Spaces. Other commercial e-LS providers chosen by the experts are i3-learning solutions (2%) and Claroline (2%). Figure 4.8 shows the commercial e-LS providers used by the experts.

Commercial e-LS Providers



Percentage

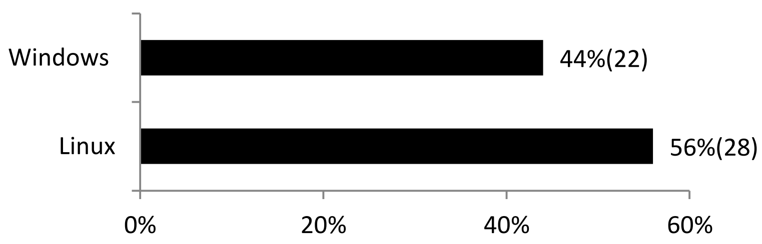
Figure 4.8: Commercial e-LS Providers

In the implementation of the e-LS, Malaysian organizations clearly prefer to use the open-source packages for their in-house development of the e-LS applications. Among these, the most popular is Moodle. In general, Moodle was chosen alongside Linux as the Operating System, MySQL as the DBMS, PHP as the programming language and Apache as the Web Server. The results drawn from the preliminary survey showed that only a few organizations opted to use commercial products. This preference may be due to cost constraints or the wider flexibility offered by the open source software as compared to commercial products. The survey had revealed that 3% of the experts had also considered other software packages (deployment tools) when in the process of implementing e-learning.

d. Operating Systems

Linux was found to be the Operating System of choice for many experts in the implementation of e-learning. The results of the survey showed that 56% of the experts were using Linux, followed by Microsoft Windows at 44%. None of the experts reported using Mac OS or Solaris in their organization. The breakdown of the types of Operating System used in organizations is shown in Figure 4.9.

Types of Operating System for e-LS



Percentage

Figure 4.9: Types of Operating System for e-LS

e. DBMS for e-LS

In looking at the Database Management System (DBMS) which can also be used in the implementation of e-learning, the survey indicated that 76% of the experts were using MySQL, 20% were using SQL Server while only 4% were using Oracle. This reflects the preference of the experts for the open source DBMS when implementing e-learning, as shown in Figure 4.10.

Types of DBMS Used for e-LS

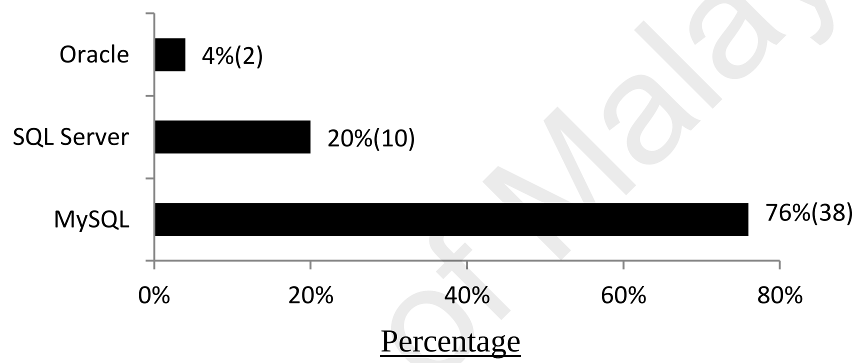


Figure 4.10: Types of DBMS Used for e-LS

f. Programming Language

The findings of the preliminary survey also demonstrated that the most commonly used programming language for the e-LS implementation was PHP, which was used by 94% of the experts. Only 20% used the Java script and a miniscule 4% chose other programming languages such as JSP and ASP.Net. The experts' preference of the programing languages used for the e-LS implementation is illustrated in Figure 4.11.

Programming Language Used for e-LS

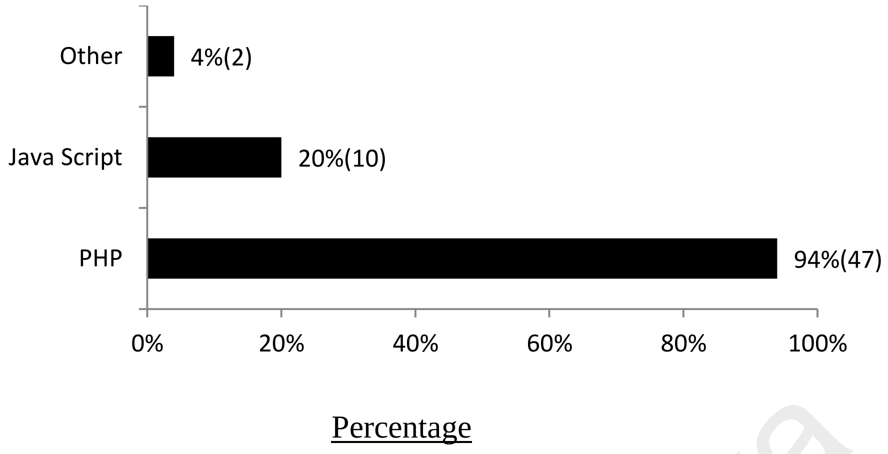


Figure 4.11: Programming Language Used for e-LS.

g. Tools for Web Server

In looking at the tools applied for the web server, the findings of the survey highlighted that 82% of the experts used Apache while only 14% used Microsoft IIS. A small percentage of 4% used other web servers as displayed in Figure 4.12.

Type of Web Server

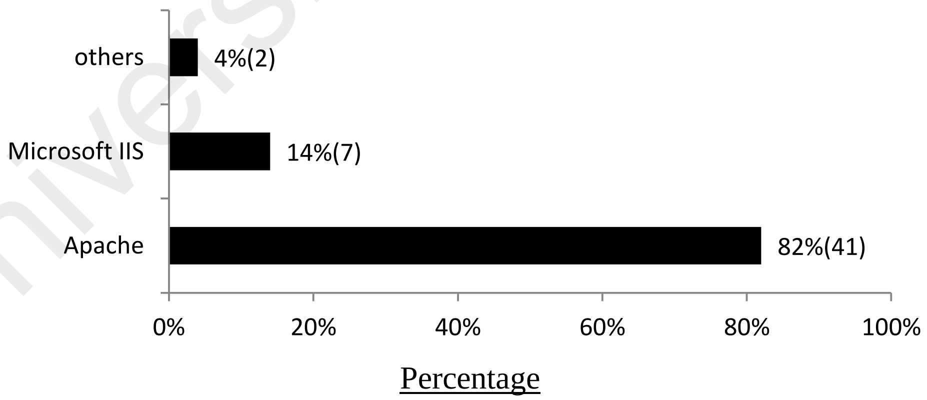


Figure 4.12: Type of Web Server

4.3.2 Stages and Methods in the Evaluation and Selection of e-LS

a. People Involved in the Process of Selecting e-LS

The preliminary survey also provided information showing the personnel's who were involved in the evaluation and selection process. It was observed that 76% of the people involved were technical experts. This is followed by 68% of the top management personnel and 14% were software vendors/suppliers and only 8% of the people involved were the end users.

Based on this finding, it can be deduced that most organizations tend to involve their technical experts and their top management people. Only a small number of these organizations (based on the experts) may invite software vendors/suppliers to be involved while end users seemed to be rarely invited to participate in the evaluation and selection process of the e-LS. Figure 4.13 shows the breakdown of the people involved in the process.

People Involved in the Process of Evaluating and Selecting e-LS

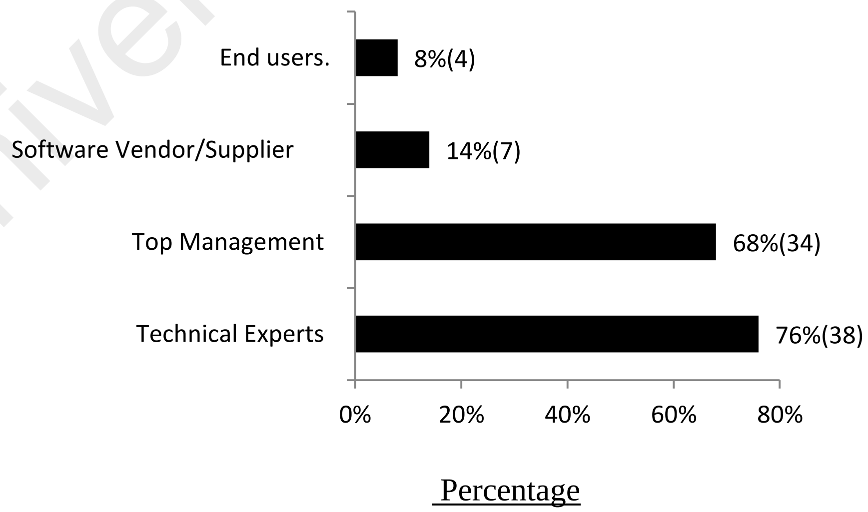


Figure 4.13: People Involved in the Process of Evaluating and Selecting e-LS

b. Stages in the Evaluation and Selection of the e-LS

Literature (Van Staaden, 2008; Jadhav & Sonar, 2009; Jadhav & Sonar, 2011) have suggested that the evaluation process of a software incurs many stages. These have been identified and adequately discussed in section 2.4. In general, there are eight stages in a normal software evaluation process. These stages follow an orderly format although no specific stage has been explicitly identified to be more important than another.

Results from the preliminary survey noted that 84% of t he experts would conduct a preliminary investigation stage and 68% of the experts claimed to have gone through the requirement definition. At this stage, the needs and requirements for purchasing the software were determined. The survey also noted that 68% of the experts had short listed some software packages. They claimed that they would screen the software packages prior to purchasing. Moreover, vendors who did not provide the essential functionalities and required features of the software would not be entertained. From the survey, more than half or 60% of the experts had also evaluated the software packages that were delivered to them.

At this stage, the metrics of the software would be defined and the weights would be assigned to the evaluation criteria. The experts claimed that during the evaluation process, the delivered software would then be rated against each of the criterion that had been designated. Among the experts, 58% also mentioned that they would select the software package that meets their requirement. In the selection process of the software, the alternative which obtained the best score would be selected for implementation. It appears that 52% of the experts have also established the criteria for the evaluation prior to the evaluation process. Thus far, 36% of the experts have purchased and implemented a software package that was most appropriate to their respective organizations. During the evaluation stage, 22% of the experts also included some negotiation activities with the software vendor so as to reach a better compromise. During this stage, software prices, software specifications, vendor capabilities and vendor support were also negotiated and agreed to.

The results of the preliminary survey indicated that some experts viewed this stage as one of the least important and it was mentioned that this stage could be omitted. From the findings, it can thus be deduced that not all the stages of the evaluation and selection process of the e-LS would be abided by the experts since some may choose to skip a few stages. The stages and methods identified from the literature and the choices made by the experts are presented in Table 4.3.

Table 4.3: Stages and Methods in the Evaluation and Selection of the e-LS

The Stages and Method in the Evaluation and Selection e-LS	**N**	**Percentage**
Requirement definition: determining the needs and requirements for purchasing the software	34	68%
Preliminary investigation: searching on the availability of software package that might be potential candidates, including an investigation of major functionalities and features of the software package provided by vendor.	42	84%
Short listing packages: screening the software package and candidates that do not provide essential functionalities and required features are eliminated.	34	68%
Establishing evaluation criteria for evaluation: criteria to be used for evaluation of the software packages are identified. Each evaluation criteria is arranged in hierarchical tree structure format and each branch ends into well-defined and measurable basic attribute	26	52%
Evaluating software packages: metrics are defined and weights are assigned to each basic attribute or and rating is done against each criterion for each software considered for detailed evaluation	30	60%
Selecting software package: rank available alternatives in descending order of the score and select the best software	29	58%
Negotiating the software vendor: Negotiate vendor about the prices, capabilities, specification, capabilities of software package and vendor support	14	22%
Purchasing and implementing the most appropriate software package.	18	36%
Other	0	

The preliminary survey had investigated the organizations' adherence to the stages involved in the evaluation and selection process but the findings indicated that almost all of the experts did not strictly adhere to all the stages, with 94% of them selectively choosing some of the stages. The findings are further illustrated in Figure 4.14.

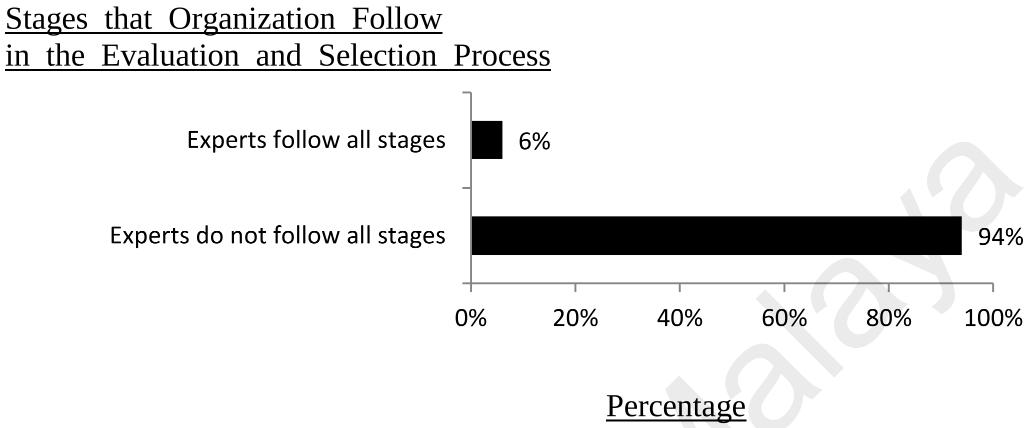


Figure 4.14: Stages that Organization Follow in the Evaluation and Selection Process

c. Identifying the e-LS

The survey had also attempted to uncover how the organizations identify the e-Learning software for use in their organizations. The findings indicated that 64% of the experts relied on internal meetings and product brainstorming to identify the selection criteria for the e-LS concerned. Less than half or 44% obtained the required information from ad-hoc meetings, 42% gathered ideas from the websites through internet surfing, 30% of them referred to end users, 28% of them requested for proposals from vendors, 28% also contacted and interviewed the end users while only 20% referred to pamphlets, catalogues, articles, and product documentations to get an idea. Figure 4.15 shows the approaches taken by organizations in identifying the evaluation criteria.

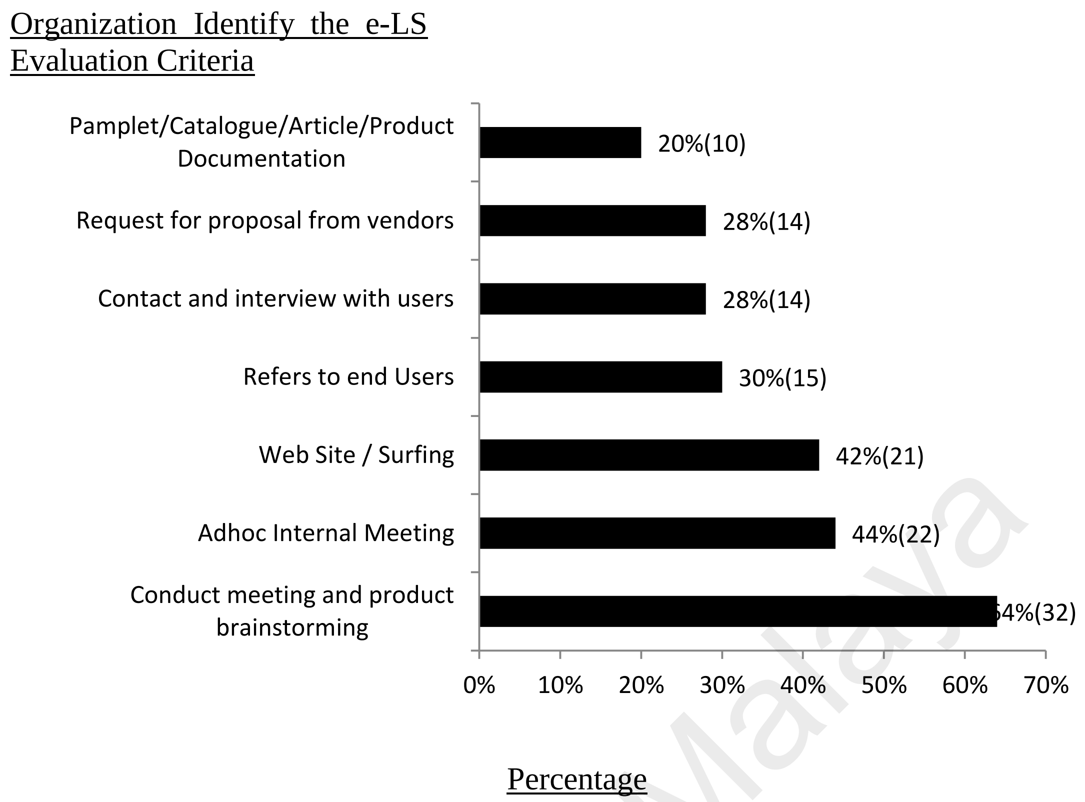


Figure 4.15: How Organization Identify the e-LS Evaluation Criteria

d. The Methods and Techniques used in the Evaluation Process of the e-LS

In the survey, the experts were also asked to select the methods and techniques used for the evaluation and selection of the e-LS. The survey data indicated that more than half or 68% of the experts claimed that they conduct internal meetings while 66% opted for a review of documentations, pamphlets and articles from the software providers. Among the experts, 28% used the weight method; 24% used the benchmark reports, 18% used the rank technique, 16% used the scoring method and only 4% used the AHP evaluation technique. None of the experts utilized more advanced processes such as the Fuzzy AHP technique. The experts did not give any information when queried on other methods and evaluation techniques. The methods and techniques applied in the evaluation process are shown in Figure 4.16.

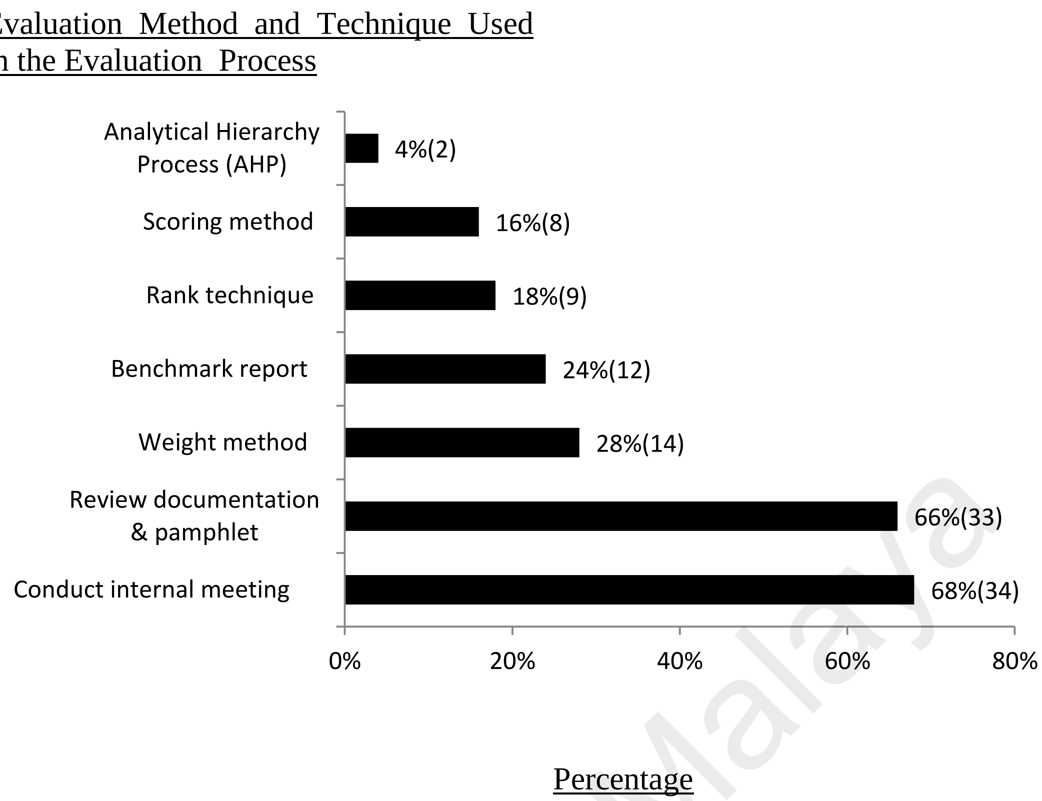


Figure 4.16: Evaluation Methods and Technique Used in the e-LS Evaluation Process

4.3.3 Identification of the Evaluation Criteria

a. Determining and Establishing the Evaluation Criteria

From the survey that also asked how the experts cum organizations, identify the evaluation criteria of e-Learning, 54% claimed to have obtained information from the internet, 22% had conducted internal meeting and brainstorming sessions; 30% had relied on the evaluation criteria provided by vendors, 20% contacted and interviewed users, and 18% referred to pamphlets/catalogues/articles or product documentation. The findings also showed that only 6% of these experts referred to the ISO/IEC 9126-1 Quality Model in order to determine the evaluation criteria of the e-LS. This is probably due to the universal nature of the ISO/IEC 9126-1 Quality Model which outlines only the general criteria for software selection. Based on this outcome, it appears that organizations in Malaysia prefer to obtain information from the internet to gather information relevant to the e-LS evaluation process. Figure 4.17 illustrates how organizations determine the evaluation criteria of the e-LS.

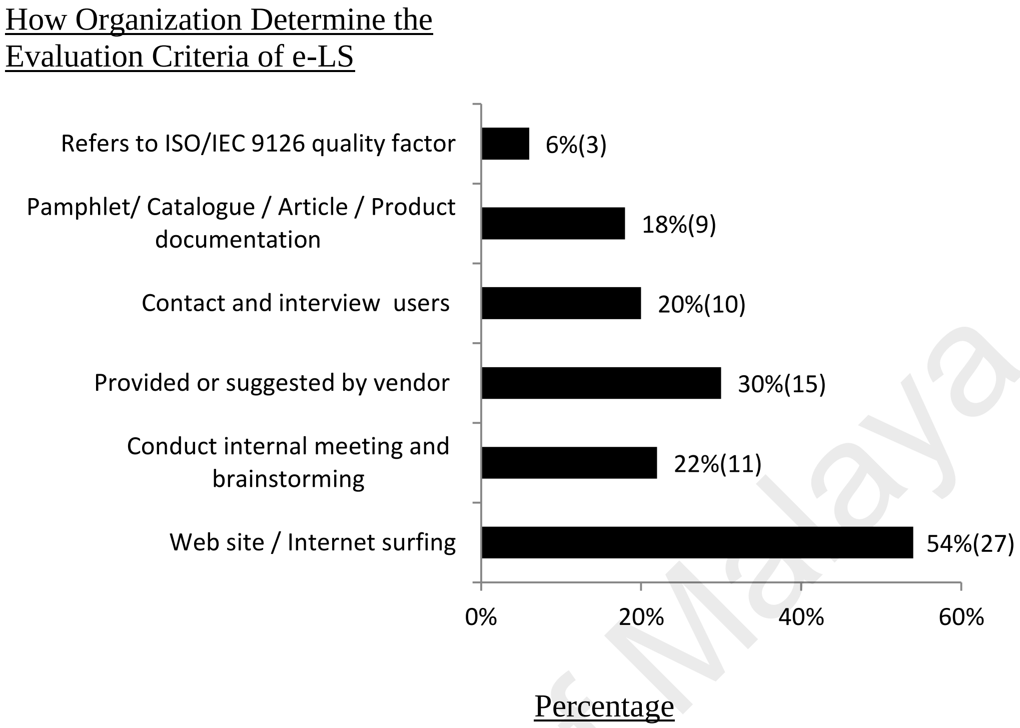


Figure 4.17: How Organization Determine the Evaluation Criteria of e-LS

b. The e-LS Evaluation Criteria

In the preliminary survey, the experts were also queried about the evaluation criteria they would consider when evaluating and selecting the e-LS. The findings noted that there was a total of 11 commonly considered evaluation criteria. It appears that six (6) of these evaluation criteria were from the ISO/IEC 9126-1 factors: *Functionality, Usability, Maintainability, Reliability, Efficiency* and *Portability*. The other five (5) criteria were *Cost*, *Vendor*, *Product Benefit*, *Risk and Uncertainty* and *Organizational*. This finding suggests that 94% of the experts chose the *Cost* criteria, 90% chose *Functionality,* 76% chose *Maintainability,* 78% chose *Usability,* 74% chose *Reliability,* and 60% chose *Efficiency*. In addition, 56% of the experts selected the *Vendor* criteria, 54% chose *Product Benefit,* 52% chose *Portability*; and 42% chose

Risk and Uncertainty. The least considered was the *Organizational* criteria. This outcome is also shown in Figure 4.18.

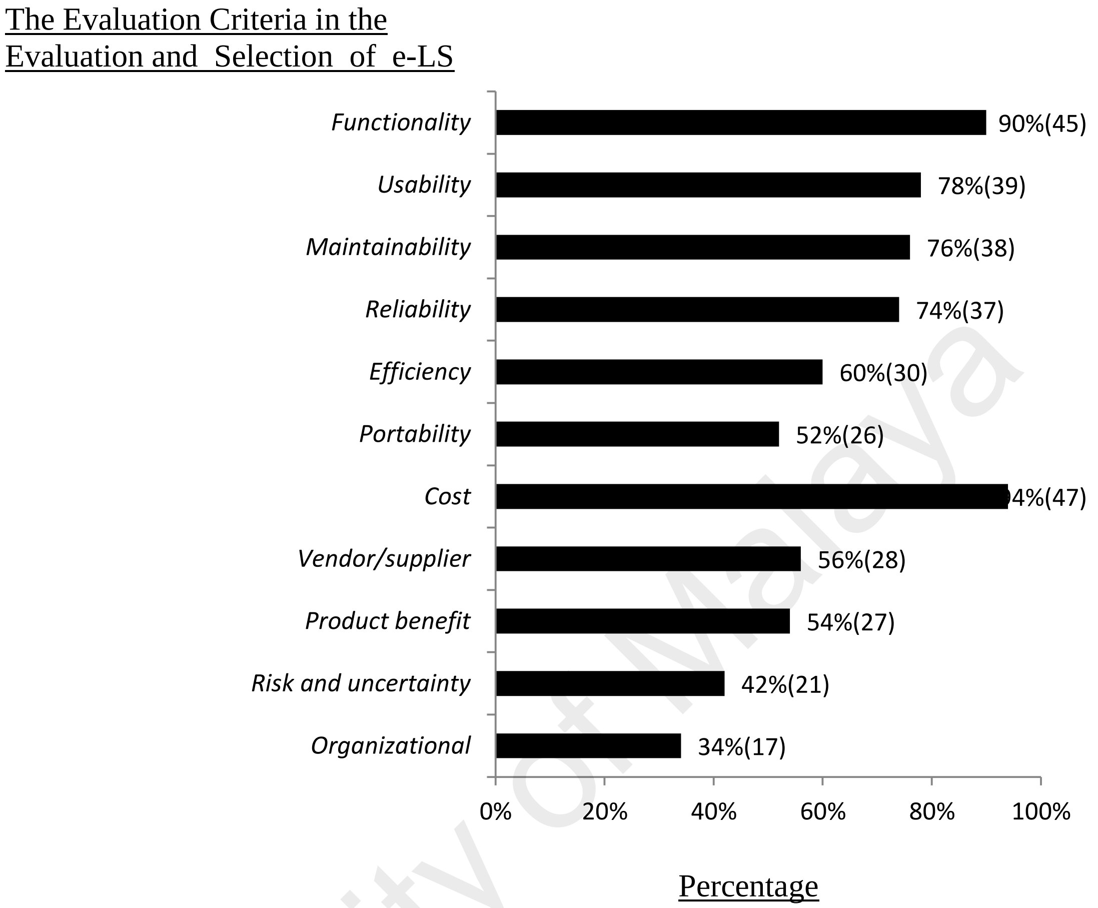


Figure 4.18: The Evaluation Criteria in the Evaluation and Selection of e-LS

4.3.4 Tool for the evaluation and selection of e-LS

a. Support Tools

In the preliminary questionnaire, the experts were asked about the support tools used, the effectiveness of the tools and whether or not the tools had assisted them. The findings showed that only 14% (7) of the experts had indicated that their organizations used support tools in the e-LS evaluation process. Figure 4.19 displays the percentage of the organizations using support tools to evaluate the e-LS.

Organization Using Support Tool
to Assist in the Evaluation of the e-LS

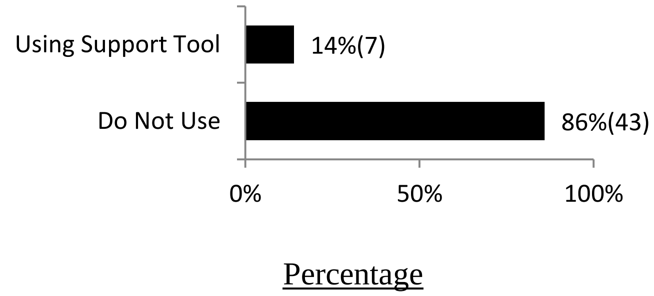


Figure 4.19: Organization Using Support Tool to Assist in the Evaluation of the e-LS

The preliminary survey showed that of the seven experts or 14% who do use support tools in their evaluation process, six (6) were using spreadsheet programs (e.g. Microsoft Excel, Lotus Notes) while only one was using a dedicated decision making software called Expert Choice, to assist the evaluation process.

b. Is the Support Tool Effective?

In this context, only one out of the seven experts who were using support tools responded that the software tool had effectively assisted his organization in the selection process. The other six experts replied that they did not find the support tools to be helpful. Figure 4.20 illustrates the responses drawn from the experts on the effectiveness of the support tools.

Effectiveness of the
Support Tool

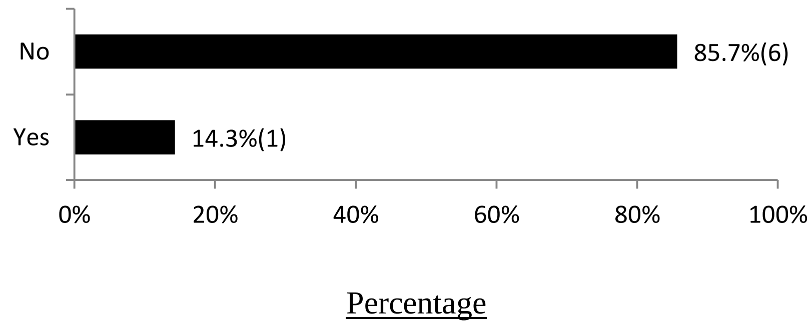
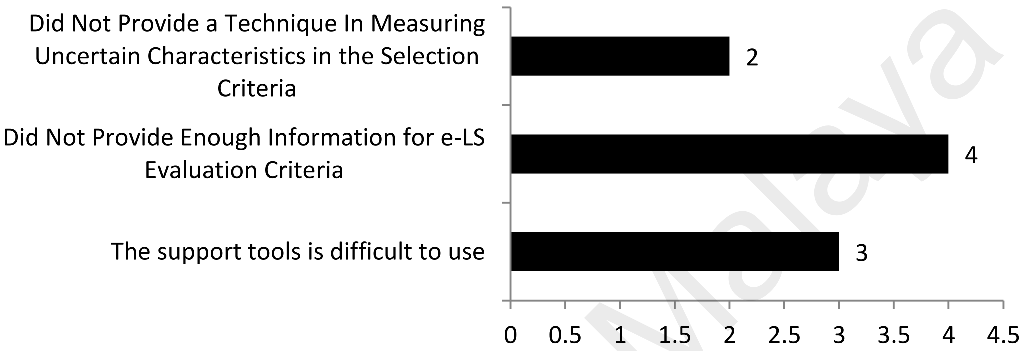


Figure 4.20: Effectiveness of the Support Tool

In looking at the effectiveness of the support tool, 33% (3) noted that the support tool was difficult to use, 45% (4) thought that the support tool was not informative enough to develop the e-LS selection criteria and software metrics for decision making and 22% (2) reported that the software did not provide any technique for measuring uncertain characteristics in the selection criteria, as shown in Figure 4.21.

Why the Support Tool Was Not Effective ?



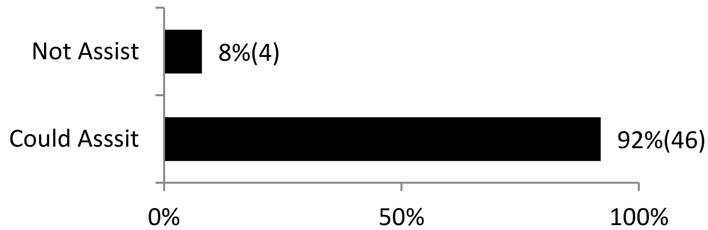
Percentage

Figure 4.21: Why the Support Tool Was Not Effective ?

c. The Need for Support Tools

When asked whether the support tools could assist in the evaluation and selection process of the e-LS, a majority or 92% (46) of the experts indicated that support tools could assist in the process. Figure 4.22 shows the experts' opinions.

Support Tools Could Assist in the Evaluation Process



Percentage

Figure 4.22: Experts' Opinion on Whether Support Tools Could Assist in the Evaluation Process

4.3.5 Problems in the Process of Evaluating and Selecting the e-LS

The survey also asked the experts to indicate whether their organizations faced any problems in the evaluation and selection process. The findings revealed that 50% of the experts agreed that there were problems caused by the lack of information and knowledge about the e-LS selection criteria, 48% noted that some specific information about the e-LS selection criteria was unreliable, not fully trustworthy as well as risky in nature because much of the information had been obtained from the internet, 26% reported on the uncertain and subjective characteristics of the selection criteria, thereby, making it difficult to assign weight or to provide an exact judgment for the evaluation process. In total, 22% mentioned a lack of guideline that can be used by organizations when reviewing the e-LS. In addition, 18% of the experts thought that placing too much dependency on the vendors was also a problem while 16% noted that the lack of support tools was a problem. Only a few of them, such as 8%, complained that the selection process was time consuming and 6% stated that the problem was the difficulty in applying the evaluation technique. From the data, the experts also provided three additional problems not included in the list. The various problems encountered by the organizations in the evaluation and selection process of the e-LS are presented in Figure 4.23.

Problems in the Process of Evaluating and Selecting e-LS

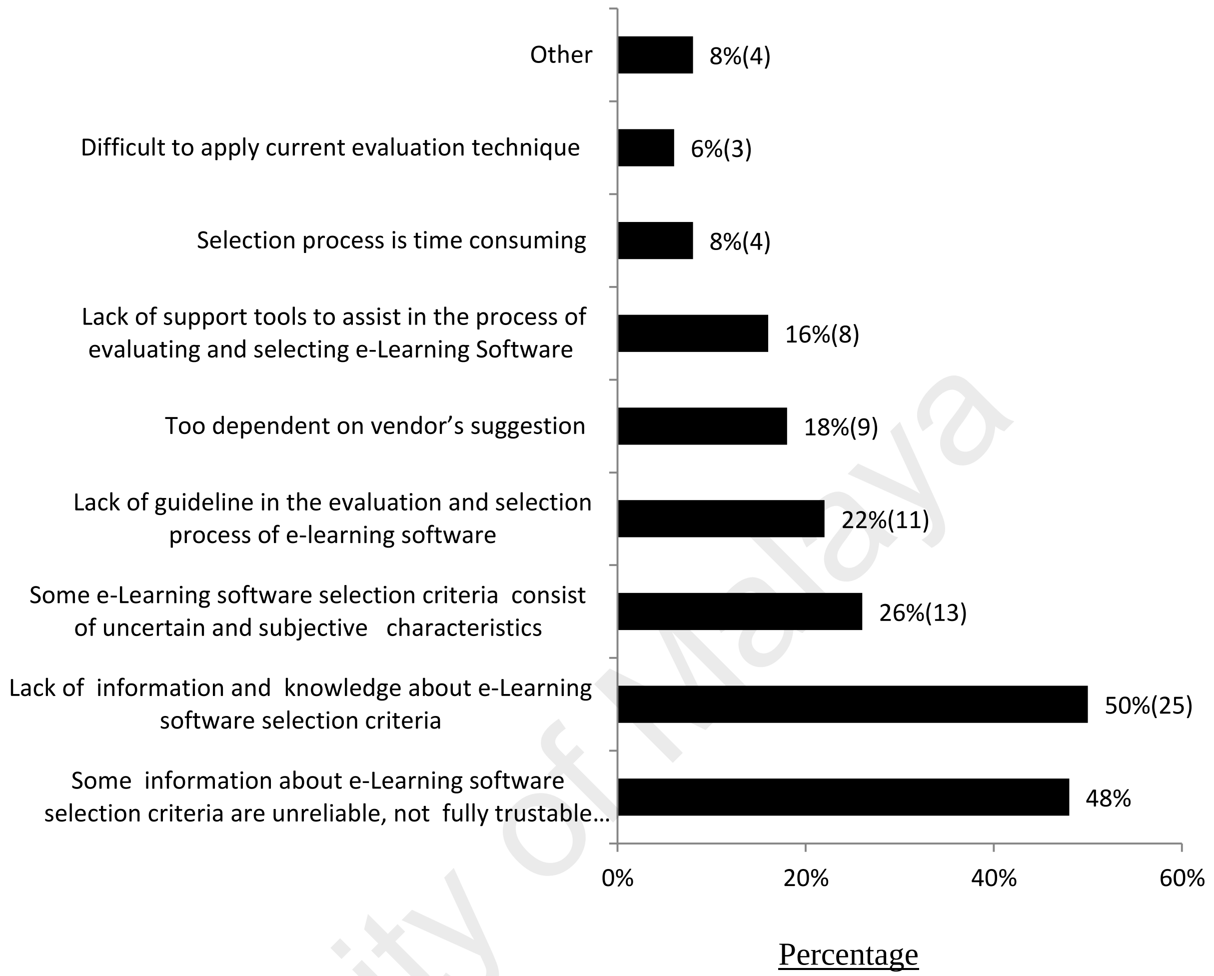


Figure 4.23: Problems in the Process of Evaluating and Selecting e-LS

In addition to the above problems, 10 experts also provided an additional five problems not included in the questionnaire. They include:

i. The e-LS does not satisfy requirements (6 experts)

ii. The e-LS contain bugs (4 experts)

iii. Vendor lock in to the e-LS (2 experts)

iv. Unused e-LS (5 experts).

v. Cost increase (6 experts).

4.4 Discussion

The findings of the five areas of interest are further discussed.

a. E-Learning Implementation

A suitable e-LS procurement process is an important process for organizations before e-Learning can be implemented. In the context of this study, only experts (organizations) using the e-LS in their e-Learning implementation were selected to participate in the preliminary survey.

The information obtained from the survey showed that organizations tend to get the technical experts and top management people to be involved in the evaluation and selection process of the e-LS. The reason for organizations doing this may be attributed to the technical nature of the e-LS as it involves online applications. Thus, it was inevitable for the organizations to require technical experts to provide their expert judgment from the technical perspective. In addition, the involvement of the top management people was necessary as the procurement process of the e-LS would involve costs and expenses which is part and parcel of the organizations' strategic planning.

b. Stages and Methods in the Evaluation and Selection of the e-LS

The stages involved in the e-LS evaluation and selection process have been discussed in section 2.4.1. It was interesting to note that organizations do not strictly adhere to the stages involved in the evaluation and selection of the software, as recommended by Jadhav and Sonar (2009; 2011) when evaluating and selecting the e-LS. It appears that organizations chose to follow only certain selected stages. The reason for this could be due to cost constraints and time constraints since cost affect the organizations' budget while time constraints may result in organizations becoming too dependent on vendor's suggestions and expertise for every aspect of the e-LS. These consequences have been noted by Nettleton (2003) to be costly and risky for the organization. It was also mentioned that in such vendor-dependent scenarios, organizations may find themselves to become 'vendor-locked' into the e-LS products. When the organizations become too dependent on a vendor for products and services, there is no more freedom for the organizations to select other vendors or work on their own without incurring substantial switching costs, whether real or perceived (Siemens, 2006).

From the outcome noted in the preliminary survey, it was evident that at least one educational organization had paid a significant amount of money to the vendor just to maintain the license of the e-LS product only. The other findings extracted from the preliminary survey suggest that the experts had to establish the criteria for the evaluation themselves when they were evaluating the software packages. This was particularly done by rating the criteria against each other in the software product. Establishing the criteria and evaluating the e-LS product are two essential stages which all experts would be expected to implement in their evaluation and selection process. Nonetheless, when experts chose to omit some stages, it could be because these stages were complex or too tedious for the entire evaluation and selection process. Moreover, these stages which have been identified from the literature were applied merely as a guideline since they were also general in nature. It is suggested that such inconsistencies noted in the adherence to the evaluation stages be further defined for future e-LS evaluation processes.

c. How Organizations Identify the e-LS

From the preliminary survey, it was noted that organizations have their own preference in identifying the e-LS to be included in the evaluation process. Most of these organizations seemed to prefer using the internet to obtain the information they require. To some scholars (Nettleton, 2003; Siemens, 2006) such a process is considered risky because the internet is not the most reliable source for information thus verifying the accuracy of a particular e-LS product may be difficult.

d. Methods and Techniques

The survey also revealed that holding internal meetings and reviewing specific documentations such as pamphlets and articles from software providers were commonly practised by the experts. Since one of the essential steps in the evaluation and selection process of the e-LS is the evaluation technique used, the survey also uncovered that the techniques reported in the literature encompassing weight method, rank method, storing, AHP technique and the Fuzzy AHP technique were not completely utilized by the organizations in Malaysia. Instead, most of these organizations relied on their own techniques such as holding internal meetings, reviewing documentations as well as the weight method and benchmark reports. A few organizations utilized the AHP technique but none used the Fuzzy AHP technique in their evaluation process. Based on this, it can be concluded that organizations do not follow a standard procedure in the evaluation and selection process of the e-LS.

e. Determining and Establishing the Evaluation Criteria

The preliminary survey also highlighted how organizations determine and establish the evaluation criteria for their evaluation and selection process. It appears that information on evaluation criteria can be obtained from various sources such as benchmark reports as well as Request for Proposal from vendors which may also include vendor's technical reports. The other preferences of the organizations can be traced to internet surfing and holding internal meetings to determine the evaluation criteria. It was also explained earlier that one useful and more commonly used resource for determining the evaluation/selection criteria for the purpose of evaluating software products is the ISO/IEC 9126-1 Quality Model (ISO/IEC9126-1, 2001). It was also mentioned that this model has a list of evaluation criteria to be considered and they include *Functionality, Usability, Maintainability, Reliability, Efficiency* and *Portability*. However, from the survey conducted, only a small number of the organizations had referred to this model.

f. Evaluation Criteria

Literature has indicated that the ISO/IEC 9126-1 Quality Model criteria are also commonly considered in the evaluation and selection process of the e-LS. From the survey, organizations also consider C*ost*, *Vendor*, *Product Benefit* and *Risk and Uncertainty* as additional evaluation criteria as needed by their organization. This implies that the ISO/IEC 9126-1 Quality Model may not be adequate for the evaluation and selection process of the e-LS. Therefore, organizations should also consider using other criteria not included the ISO 9126-1 quality model in the evaluation process of the e-LS.

g. Software or Support Tools for the Evaluation Process of the e-LS

Considering the complexity of the evaluation and selection process of the e-LS, it is thus surprising to find that a few organizations were making use of support tools to assist them in the evaluation process. Of those who do, most had only used a general spreadsheet software such as Microsoft Excel. In contrast, a specialized decision making tool should consider Expert Choice. The preliminary survey also noted that organizations using the support tools were complaining about their ineffectiveness. Many claimed that they were not effective, difficult to use, did not have enough information about the evaluation criteria and metrics, and were unable to measure uncertain characteristics noted in the e-LS evaluation criteria. Nonetheless, among those organizations which were not using support tools, it was observed that they were of the opinion that having support tools to assist their evaluation and selection process could be beneficial to their organizations.

h. Effectiveness of the Software or Support Tools.

The reasons quoted for the ineffectiveness of the software include: 1) it did not provide enough information about selection criteria e-LS and software metrics for decision making, 2) it was difficult to use, and 3) it did not have the ability to measure uncertain characteristics of the e-LS criteria. This implies that incorporating more information about the evaluation criteria and sub-criteria into the development of the software tools is necessary since majority of the expert respondents had shown a favorable response to the availability of support tools.

i. Problems in the Process of Evaluating and Selecting the e-LS

Three top problems involved in the evaluation and selection process of the e-LS were found to be related to the evaluation criteria. Majority of the experts were of the opinion that some information about the e-LS evaluation criteria obtained from the internet was unreliable, not fully trustworthy and risky in nature. Thus, the most common problem faced by organizations in Malaysia is the unreliable source of the information. Another problem is the lack of information and knowledge about the e-LS selection criteria. Some experts have also noted that the lack of a standard guideline that can be used in the evaluation and selection process of the e-LS created a problem for the organizations. Other experts expressed the problem with assigning weights or providing exact judgments for criteria that seemed uncertain or subjective in nature. Other problems include organizations’ over-dependency on vendors, the lack of support tools and the time consumed in the evaluation process. From the perspective of the evaluation technique, it can be seen that problems arise in the application of the evaluation technique. This is because there is no one particular guideline for organizations to follow when implementing the evaluation and selection process of the e-LS. Moreover, the evaluation criteria proposed by literature have not been consistent. Therefore, it is suggested that a set of evaluation criteria and sub criteria be determined for use in the evaluation of the e-LS.

4.5 Summary

The aim of the preliminary survey was to investigate the current practices noted in the evaluation and selection process of the e-LS among organizations in Malaysia. The results obtained were presented and the issues were highlighted from five perspectives encompassing: Implementation in e-Learning, Stages and methods in the evaluation and selection process of the of e-LS; Identification of the evaluation criteria; Support tools used and Problems encountered in the evaluation and selection process. The results showed some similarities with issues that had been highlighted in the literature focusing on e-LS evaluations which point to the fact that there is no appropriate standard procedure for organizations to follow when evaluating the e-LS. The most significant result that can be drawn from the preliminary survey, as reported in this chapter, can be traced to the lack of a standard guideline for the e-LS evaluation process. This is followed by the limitation of a software quality model that contains relevant e-LS evaluation criteria compounded by the inaccessibility of a user-friendly tool to assist in the e-LS evaluation process. From the limitations noted of the current practices, this study aims to develop a systematic guideline that contains a sequence of processes that use appropriate techniques which can be used by organizations when evaluating the e-LS. A software tool to assist organizations in the evaluation process would also be beneficial. These two desirable materials can help to enhance the performance of organizations which are currently experiencing a manual process in evaluating the e-LS.

CHAPTER 5: FORMULATION OF THE ISQM-FUZZY AHP EVALUATION FRAMEWORK FOR E-LEARNING SOFTWARE EVALUATION

5.1 Introduction

Chapter 5 describes the formulation of the ISQM–Fuzzy AHP evaluation framework for the e-LS evaluation. Section 5.2 of this chapter discusses the evaluation criteria for the e-LS evaluation which can be used for the development of the ISQM. It covers the criteria and sub-criteria obtained from literature. The additional criteria obtained from the Delphi survey is discussed in Section 5.3. The definition of the quality model has been discussed in Section 2.5.1. The construction of the ISQM is further discussed in Section 5.4. The ISQM constructed in this study is conceptually similar to the ISO/IEC 9126-1 Quality Model used for software evaluation. However, it will consists of more criteria and sub-criteria that are relevant to be used for the e-LS evaluation. The ISQM is developed prior to the formulation of the ISQM-Fuzzy AHP evaluation framework.

Similar to the COTS framework as defined by Comerla-Dorda et al., (2002), the ISQM-Fuzzy AHP describes how an evaluation is performed; it includes descriptions of the processes, evaluation criteria and suitable evaluation techniques involved. The ISQM-Fuzzy AHP framework will consist of a sequence of processes that will guide organizations in evaluating the e-LS. The ISQM-Fuzzy AHP evaluation framework for the e-LS is further elaborated in section 5.5. The relationship between the ISQM, the Fuzzy AHP and the e-LSO is highlight in Section 5.5. The stages and processes involved in the ISQM-Fuzzy AHP framework is discussed in Section 5.5. The framework will be used to construct a supporting tool that can assist organizations in the evaluation process of the e-LS selected.

In the context of this study, a framework is defined as a structure or system that can be used to realize a result or a goal. In contrast, a model is some design or concept used to explain a mechanism or operation of some processes.

5.2 Evaluation Criteria for the Development of the ISQM

The criteria development of the ISQM involves two stages. The first stage is the identification of the evaluation criteria from literature review, as explained in Section 3.3.1.1. The second stage involves obtaining the additional criteria from experts as well as the validation of the criteria by experts using the Delphi survey as described in Section 3.3.1.2.

5.2.1 Previous Work of Evaluation Criteria

As explained in section 3.3.1.1, based on the reading of titles and the contents of abstracts, 250 academic articles were found to be relevant to this study. The review covered topics focusing on the evaluation and selection of software, software evaluation criteria, COTS software evaluation, and the e-LS evaluation. A final list of 50 related articles were found to be specifically related to the evaluation criteria of software including the e-LS. The details of the articles are listed in Table 5.1.

Table 5.1: List of Articles from Literature

No	Authors	Title	Sources
1	Kontio et al. (1996)	Defining Factors, Goals and Criteria for Reusable Component Evaluation	The CASCON'96 Conference, Toronto Canada
2	Boehm & Port (2001)	Risk-Based Strategic Software Design: How Much COTS Evaluation is Enough?	International Workshop on Economics-Driven Software Engineering Research (EDSER-3)
3	Kitchenham & Pfleeger (1996)	Software quality: the elusive target	Software, IEEE
4	Boehm et al. (1978)	Characteristics of software quality	New York: American Elsevier
5	Dromey (1996).	Cornering the chimera	IEEE Software
6	ISO/IEC9126-1. (2001)	Software Engineering Product Quality- Part 1: Quality Model	International Standards for Organization
7	Mohamed et al. (2007)	COTS Selection: Past, Present, and Future	Proceedings of the 14th Annual IEEE International Conference and Workshops on the Engineering of Computer-Based Systems (ECBS'07)

‘Table 5.1, List of Articles from Literature Continued’

No	Authors	Title	Sources
8	Franch, & Carvallo (2003)	Using Quality Model in Software Package Selection	IEEE SOFTWARE
9	Valenti et al. (2002)	Computer based assessment systems evaluation via the ISO9126 quality model	Journal of Information Technology Education
10	Jung et al. (2004)	Measuring software product quality: A survey of ISO/IEC 9126	Software, IEEE
11	Grau et al. (2004)	DesCOTS: A Software System For Selecting COTS components	The Proceedings of the 30th EUROMICRO Conference (EUROMICRO’04)
12	Punter et al. (1997)	Software Product Evaluation	The Proceedings of the 4th IT Evaluation Conference (EVIT-97)
13	Bertoa et al. (2006)	Measuring the usability of software components	Journal of Systems and Software
14	Chua & Dyson (2004)	Applying the ISO9126 model to the evaluation of an e-learning system	Proceedings of the 21st ASCILITE Conference
15	Carvallo & Franch (2006)	Extending the ISO/IEC 9126-1 Quality model with non-Technical factors for COTS components selection	Paper presented at the WoSQ'06
16	Robert (1997)	Quality requirements for software acquisition	Software Engineering Standards Symposium And Forum, 'Emerging International Standards'
17	Pruengkarn et al. (2005)	An evaluation model for e-Learning Websites in Thailand university	The IEEE International Conference
18	Behkamal et al. (2009)	Customizing ISO 9126 quality model for evaluation of B2B applications	Information and Software Technology
19	Yacoub et al. (2000)	A hierarchy of COTS certification criteria	The First Software Product Line Conference
20	Dehlin et al. (2000)	A Model for Certifying COTS Components for Product Lines	The First Software Product Line Conference
21	Jadhav & Sonar (2009)	Evaluating and selecting software packages: A review	Information and Software Technology
22	Kunda & Brooks(1999)	Applying social-technical Approach for COTS selection	The Proceedings of the 4th UKAIS Conference
23	Jadhav & Sonar (2011)	Model for evaluation and selection of the software packages: A hybrid knowledge based system approach.	The Journal of Systems and Software
24	Quer et al. (2006)	DesCOTS-SL: a tool for the selection of COTS components	The 14th IEEE International Requirements Engineering Conference (RE'06)
25	Och et al. (2000).	COTS acquisition Process: Definition and application Experience	The Proceedings of the 11th European Software Control and Metric Conference (ESCOM SCOPE 2000)
26	Ortega el al. (2003)	Construction of a systemic Quality Model For evaluating a software product	Software Quality Journal
27	Carvallo et al. (2006).	Managing non-technical requirements in COTS components selection.	The Requirements Engineering,14th IEEE International Conference
28	Bandor (2006)	Quantitative methods for software selection and evaluation	Technical Note
29	Kunda & Brooks (2000)	Identifying and classifying processes (traditional and soft factors) that support COTS component selection: a case study	European Journal of Information Systems
30	Boehm (1988)	A spiral model of software development And enhancement.	Computer

‘Table 5.1, List of Articles from Literature Continued’

No	Authors	Title	Sources
31	Sedigh-Al et al. (2001)	Software engineering metrics for COTS-based systems.	Computer
32	Sahay & Gupta (2003)	Development of software selection criteria for supply chain solutions	Industrial Management & Data Systems
33	Shoniregun & Gray (2003)	Is E-learning Really the Future or a Risk? ACM, 2003 (April 1 – April 30,2003)	ACM
34	Chau (1995)	Factors used in the selection of Packaged software in small businesses: views of owners and managers.	Information & Management
35	Pituch & Lee (2006)	The influence of system characteristics on e-learning use	Computers & Education
36	Patomviriyavong et al. (2006)	eLearning Operational Risk Assesment and management: A case study of the M.Sc in Management Program	International Journal of Computers, the Internet And Management
37	Ardito et al. (2006)	An approach to usability evaluation of e-learning applications.	Universal Access in the Information Society
38	Lanzilotti et al. (2006)	eLSE methodology: A systematic approach to the e-learning system evaluation	Educational Technology & Society
39	Graf, & List (2005)	An Evaluation of Open Source E-Learning Platforms Stressing Adaptation Issues	the Proceedings of the Fifth IEEE International Conference on Advanced Learning Technologies (ICALT’05)
40	Costabile et al. (2007)	A Holistic Approach to the Evaluation of E-Learning Systems	Universal Access in Human-Computer Interaction. Applications and Services
41	Koohang (2004)	Expanding the Concept of Usability	Informing Science Journal
42	Boot et al. (2008)	Improving the development of instructional software: Three building-block solutions to interrelate design and production	Computers in Human Behaviour
43	Kapp (2003)	Five Technological Considerations When Choosing an E-Learning Solution	learn Magazine
44	Thyagharajan & Nayak (2007)	Adaptive Content Creation for Personalized e-Learning Using Web Services	Journal of Applied Sciences Research
45	Mili et al. (1995)	Reusing Software: Issues and Research Directions	IEEE Transaction on Software Engineering
46	Merriënboer & Martens (2002)	Computer-Based Tools for Instructional Design: An Introduction to the Special Issue	ETR&D
47	Kljun et al. (2007)	Evaluating Comparisons and Evaluations of Learning Management Systems	The Proceedings of the ITI 2007 29th Int. Conf. on Information Technology Interfaces, Cavtat, Croatia
48	Van den Berg (2005)	Finding Open options :An Open Source Software evaluation Model with a case study on Course Management Systems	Master thesis
49	Du et al. (2013).	User acceptance of software as a service: Evidence from customers of China's leading e-commerce company, Alibaba	Journal of Systems and Software
50	Mehlenbacher et al. (2005)	Usable E-Learning: A c onceptual Model for Evaluation and Design	11th International Conference on Human-Computer Interaction

5.2.2 Identification of the Evaluation Criteria and Sub-Criteria from Literature Review

From the reading, 11 evaluation criteria and 66 sub-criteria for the e-LS evaluation were identified. The evaluation criteria extracted include *Functionality, Maintainability, Reliability*, *Usability, Portability, Efficiency*, *Cost*, *Vendor*, *Organizational*, *Risk and Uncertainty* and *Product Benefit*. Each criterion consists of several sub-criteria. For example, under the criteria of *Functionality,* nine sub-criteria were detected including *Suitability, Accuracy, Flexibility, Security, Interoperability, Pedagogical, Personalization, and Community* and *SCORM Compliance.* These 11 evaluation criteria and their respective sub-criteria are listed in Table 5.2.

Table 5.2: The Evaluation Criteria and Sub-Criteria Extracted from Literature Review

Criteria	Source
Functionality	**1,2,3,5,6,7,8,9,10,11,12,14,15,16,17,18,19,20,21,22,23,24,25,26,37,38,39,40, 43, 44,47,48,50**
Suitability	3,6,8,24,25,26
Accuracy	3,6,7,8,24,26
Flexibility	2,3,6,8,15,17,24,50
Security	1,2,3,6,7,8,9,10,12,15,16,17,18,19,22,24,26,47
Interoperability	1,3,6,7,8,9,10,12,15,17,19,20,22,24,25,26
Pedagogical	37,38,40
Personalization	39,44,47
Community	47,48
SCORM Compliance	43,47
Maintainability	**1,3,5,6,7,8,9,10,14,15,16,17,18,21,22,23,24,25,26,42,43,47,48**
Changeability	1,3,6,7,8,10,11,15,16,17,18,24,26
Stability	3,5,6,8,10,12,15,17,18,24,26,47
Analyzability	3,6,8,10,15,17,18,24,26
Testability	1,3,6,7,8,10,12,15,17,18,19,24,26
Modularity	21,43,47,48
Scalability	21,23,42,47
Reliability	**1,3,5,6,7,8,9,10,11,12,14,15,16,17,18,21,22,23,24,25,26**
Maturity	2,3, 6 ,7,8,10, 12,13,14, 17,18, 24,26
Fault Tolerance	1, 3, 6, 8, 10, 12,15, 17,18, 24,26
Backup and Recovery	1, 3, 6, 8, 10, 12,15, 17,18, 24,26
Usability	**1,3,5,6,7,8,9 ,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26, 37,38,40,41, 42,46,50**
Understandability	1,,3,6,7,8,9,10,12,13.15,17,18,19,20,24.26,41
Learnability	1,3,6,8,9,10,12,13,15,16,17,24,26,41,50
Operability	1,3,6,8,9,10,12,13,15,17,18,24,26
Customizability	3,6,8,10,13,15,17,18,24,46, 50
Hypermediality	37,38,40
Support Tools	37
Presentation	37,38,40
User Interface	21,23
Learning Contents	38,40,41

‘Table 5.2, The Evaluation Criteria and Sub-Criteria Extracted from Literature Review Continued’

Criteria	Source
Portability	**1,2,3,5,6,7,8,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,39, 42,46**
Adaptability	1,3,6,8,10,12,15,17,18,19,20,21,22,24,26,39,42,46
Installability	1,2,3,6,8,10,12,15,17,18,24,26
Conformance	1,3,6,8,10,15,17,24
Replaceability	3,6,8,10,12,15,17,18,24,26
DBMS Standards	21,23
Middleware Standards	21,23
Efficiency	**1,3,5,6,8,10,11,12,15,16,17,18,21,22,23,24,26**
Time Behaviour	1,3,6,8,10,11,12,15,16,17,18,21,23,24,24,26
Recourse behaviour	1,3,6,8,10,11,12,15,16,17,18,21,23,24,24,26
Cost	**1,2,15,21,23,25,27,30,32,33,34,35,47,48**
Licensing Cost	15,22,27,32,35,47,48
Development Cost	15,27
Implementation Cost	15,27,30,32,33
Maintenance Cost	1,27,33
Upgrade Cost	32
Cost of Hardware	21,23
Training Cost	21,23
Vendor	**1,2,15,19,20,21,22,23,27,28,29,30,32,34,43**
Vendor Reputation	15,19,20,27,29,30,34,43
Vendor Support & Training	2,19,22,27,28,29,30,32,34
Vendor Services	1,15,19,20,22,27,32,34
User Manual/Documentation	21,23
Tutorial	21,23
Troubleshooting Guide	21,23
Training	21,23
Maintenance and Upgrading	21,23
Communication	21,23
Demo	21,23
Response Time	21,23
Length of Experience	21,23
Technical and Business Skills	21,23
Past Business Experience	21,23
Organizational	**15,22,30,45,49**
Organizational Culture	30
Organizational Change	15,45
Organizational Politics	22,30
Organizational Resource	15,45
User Acceptance	49
Product Benefit	**21,27,34,35,41,50**
User Satisfaction	41,50
Software Ease of Use	34,35
Risk and Uncertainty	**2,4,25,33,36,48**
Vendor Risk	2,25,33
Product/Technological Risk	2,4,25,33,36,48
Software Bugs and Errors	4,36

Based on the review of 50 papers, the number and the percentage of each criterion were calculated. Table 5.3 sorts the criteria according to the number and percentage of the papers that cited the criteria.

Table 5.3: Percentage of the Evaluation Criteria Cited in Literature Review

Criteria	Number of paper reviewed(n=50)	Percentage(%)
Functionality	33	66
Usability	31	62
Portability	29	58
Maintainability	22	44
Reliability	21	42
Efficiency	16	32
Vendor	15	30
Cost	14	28
Product Benefit	6	12
Risk and Uncertainty	6	12
Organizational	5	10

From the list of 50 articles reviewed, the *Functionality* criterion was found to be the highest cited criteria with a total of 33 (66%) citations. This is followed by the *Usability* criterion, mentioned in 31 (62%) papers while the *Portability* criterion was highlighted by 29 (58%) papers. In contrast, the *Product Benefit*, *Risk and Uncertainty* and *Organizational* criteria were only cited by a small number of researchers at 6 (12%), 6 (12%) and 5 (10%) citations, respectively.

The literature review also revealed that the evaluation criteria of *Functionality, Maintainability*, *Portability*, *Usability* and *Reliability* were among those commonly selected for the evaluation of a software inclusive of the e-LS. Other criteria such as *Cost*, *Vendor*, *Product Benefit* and *Risk and Uncertainty* were also important. Since the e-LS is a type of software, it is important to include these criteria in the evaluation and selection process too. In addition, since these criteria were identified from various sources, a consensus and validation by the experts was necessary. The experts were also consulted on the identification of additional criteria that had not been identified from the literature review. A Delphi method was used to obtain the consensus and opinion of the experts for the additional criteria.

5.3 The Additional Sub-Criteria Obtained from Experts by Using the Delphi Method

The Delphi method was used not just to obtain the additional evaluation criteria from the experts but also to validate all the evaluation criteria they had proposed. As mentioned in Section 3.3.1.2 the Delphi survey was used to represent the survey that was conducted through the Delphi method. The questionnaire was constructed based on the evaluation criteria identified from the literature review, as outlined in Section 3.3.1.2. The questionnaire was then given to the experts for the validation process.

5.3.1 Conducting the Delphi Survey

The first part of the questionnaire was designed to collect the demographic data of the experts. The second part described the evaluation criteria alongside their brief explanations based on the literature review. The questionnaire also requested the experts to rank each of the evaluation criterion based on their importance and to provide any additional criteria to the list. As mentioned in Section 3.3.1.2, a pilot study was conducted to ensure the questionnaire reliability before it was sent to the selected experts. The overall result showed that the value of the Cronbach's Alpha for the reliability analysis of the 11 items was 0.944. This indicates that the questionnaire has good reliability. The result also showed that the measurements were consistent. Table 5.4 shows the reliability analysis for each of the evaluation criterion.

Table 5.4: The Reliability of Evaluation Criteria Ranked by Experts

Criteria	N item	N respondents	Cronbach's Alpha
Functionality	8	6	0.710
Maintainability	6	6	0.679
Usability	9	6	0.777
Reliability	4	6	0.520
Portability	6	6	0.443
Efficiency	2	6	0.842
Cost	7	6	0.900
Vendor	14	6	0.936
Organizational	4	6	0.906
Product Benefit	2	6	0.935
Risk and Uncertainty	3	6	0.888

5.3.2 Evaluation of the Sub-Criteria of the e-LS Obtained from the Delphi Survey

This section presents the results obtained from the responses of the 31 experts. The results were divided into several sections: results from the pilot test, results of the experts' validation and consensus of the criteria and sub-criteria, results of the evaluation criteria ranked by the Technical Experts; evaluation criteria ranked by the Decision Makers, and evaluation criteria ranked by the Academician/Researchers.

Before data analysis was carried out, the reliability of each item of the evaluation criterion was checked. Altogether, there were 11 items of evaluation criteria and 66 items of sub-criteria of the e-LS. Table 5.5 shows the result of the reliability test.

Table 5.5: Reliability of the Evaluation Criteria Based on Cronbach's Alpha

Criteria	N item	N respondents	Cronbach's Alpha
Functionality	10	31	0.746
Maintainability	9	31	0.875
Usability	11	31	0.898
Reliability	5	31	0.866
Portability	7	31	0.849
Efficiency	3	31	0.873
Cost	8	31	0.848
Vendor	15	31	0.945
Organizational	5	31	0.926
Product Benefit	5	31	0.949
Risk and Uncertainty	7	31	0.932

The results indicated that the items measured, constitute a highly reliable construct where the overall Cronbach's Alpha obtained from the 11 items of the evaluation criteria was 0.844. Hence, each evaluation criterion of the e-LS was highly reliable to elicit relevant data that can be used for the development of the ISQM.

5.3.3 Experts' Consensus on the Evaluation Criteria and Sub-Criteria of the e-LS

Using the Delphi Survey, the experts were also requested to express their opinions about the evaluation criteria and sub-criteria listed. The IQR and Median were analysed and shown from Tables 5.6 to 5.16. The results showed the movement of the consensus towards each criterion and sub-criterion in Round 1 and Round 2 of the Delphi survey.

5.3.3.1 The Consensus Among Experts With Respect to the Sub-Criteria of *Functionality*

Table 5.6 shows the consensus among experts based on the IQR and Median score for each sub-criterion of *Functionality*. After Round 2, a total of eight sub-criteria encompassing: *Suitability, Accuracy, Flexibility, Security, Interoperability, Pedagogigal, Learning Community* and *SCORM Compliance* were obtained with Good Consensus, with the IQR value of 1. The sub-criterion of *Personalization* obtained a Moderate Consensus with the IQR value of 2. The result for the level of consensus of expert showed that six sub-criteria encompassing: *Suitability, Flexibility, Security, Interoperability, Pedagogigal* and *Personalization* had obtained a consistent consensus where the same value of the IQR was obtained for both rounds of the survey. The IQR value was between Moderate Consensus (*IQR =2*) and Good Consensus (*IQR = 1*). There was also an improvement among the experts in their consensus for the sub-criterion of *SCORM Compliance* which obtained a Moderate to Good Consensus after Round 2.

One additional sub-criterion of *User/Learner Administration* obtained a High Consensus. The Median result for each of the sub-criterion of *Functionality* showed that the Median value was between 4 and 5. Therefore, all the 10 sub-criteria for *Functionality* were accepted as the Median values were not less than 3.5, as explained by Ononiwu (2013) and Pichlack (2015).

Table 5.6: Consensus Among Experts With Respect to the Sub-Criteria of *Functionality*

	Round 1			Round 2		
Sub-Criteria	IQR	Median	Level of Consensus	IQR	Median	Level of Consensus
Suitability	1	4	Good Consensus	1	5	Good Consensus
Accuracy	2	4	Moderate Consensus	1	5	Good Consensus
Flexibility	1	4	Good Consensus	1	4	Good Consensus
Security	1	5	Good Consensus	1	5	Good Consensus
Interoperability	1	4	Good Consensus	1	4	Good Consensus
Pedagogical	1	4	Good Consensus	1	4	Good Consensus
Personalization	2	4	Moderate Consensus	2	4	Moderate Consensus
Learning Community	1	4	Good Consensus	1	5	Good Consensus
SCORM Compliance	2	4	Moderate Consensus	1	4	Good Consensus
User/Learner Administration (New Sub-Criteria)	-	-	-	***0***	***4***	***High Consensus***

5.3.3.2 The Consensus Among Experts With Respect to the Sub-Criteria of *Maintainability*

Table 5.7 shows the consensus of the experts, based on the IQR and Median score, for each sub-criterion under *Maintainability*. After Round 2, six sub-criteria encompassing: *Changeability, Stability, Analysability, Scalability, Fault Software* and *Error Preventing* obtained a Good Consensus with the IQR value of 1. The sub-criterion of *Testability* obtained a Moderate Consensus with the IQR value of 2. The result for the level of consensus among the experts showed that two sub-criteria of *Changeability* and *Testability* obtained a consistent consensus where the same value of the IQR was obtained for both rounds. The IQR value was between Moderate Consensus (*IQR = 2*) and Good Consensus (*IQR = 1*).

There was also an improvement among experts in their consensus for the sub-criterion of *Analyzability* which obtained Moderate to Good Consensus. As for the sub-criterion of *Modularity*, the consensus obtained was from Good to High Consensus after Round 2. One additional sub-criterion of *Expansion* obtained a High Consensus. Two other additional sub-criteria of *Fault Software* and *Error Preventing* obtained a Good Consensus. The Median result for each sub-criterion of *Maintainability* showed that the Median value of 4 was obtained. Therefore, all the nine sub-criteria for *Maintainability* were accepted as the Median values were not less than 3.5 as explained by Ononiwu (2013) and Pichlack (2015).

Table 5.7: Consensus Among Experts With Respect to the Sub-Criteria of *Maintainability*

	Round 1			**Round 2**		
Sub-Criteria	IQR	Median	Level of Consensus	IQR	Median	Level of Consensus
Changeability	1	4	Good Consensus	1	4	Good Consensus
Stability	2	4	Moderate Consensus	1	4	Good Consensus
Analyzability	2	4	Moderate Consensus	1	4	Good Consensus
Testability	2	4	Moderate Consensus	2	4	Moderate Consensus
Modularity	1	4	Good Consensus	0	4	High Consensus
Scalability	2	4	Moderate Consensus	1	4	Good Consensus
Expansion (New Sub-Criteria)	-	-	-	***0***	***4***	***High Consensus***
Fault Software (New Sub-Criteria)	-	-	-	***1***	***4***	***Good Consensus***
Error Preventing (New Sub-Criteria)	-	-	-	***1***	***4***	***Good Consensus***

5.3.3.3 The Consensus Among Experts With Respect to the Sub-Criteria of *Usability*

Table 5.8 shows the experts' consensus, based on the IQR and Median score, for each sub-criterion under the Usability evaluation criteria. After Round 2, seven sub-criteria of *Understandability, Learnability, Operability, Customizability, Hypermediality, Support Tools* and *Presentation* obtained a Good Consensus with the IQR value of 1. One sub-criterion of *Learner Interface* obtained a Moderate Consensus with the IQR value of 2. The sub-criterion of *Learning Content* obtained a High Consensus with the IQR value of 0.

The result showing the level of expert consensus indicate that eight sub-criteria of: *Understandability, Learnability, Customizability, Hypermediality, Support Tools, Presentation, Learner Interface* and *Learning Content* obtained a consistent consensus where the same value of the IQR was obtained for both rounds. The IQR value was between Moderate Consensus (*IQR = 2*) and Good Consensus (*IQR = 1*).

There was also an improvement in the experts' consensus for the sub-criterion of *Operability* which obtained a Moderate to Good Consensus after Round 2. There was also an improvement in the Median value which moved from 4 to 5 for *Learnability*. This shows that the number of experts who agreed with the *Learnability* criterion had increased. One additional sub-criterion of *Accessibility Control* obtained a High Consensus. After Round 2, the Median result for each sub-criterion of the *Usability* evaluation criteria was also between 4 and 5. Therefore, all the 10 sub-criteria for *Usability* were accepted as the Median values were not less than 3.5, as explained by Ononiwu (2013) and Pichlack (2015).

Table 5.8: Consensus Among Experts With Respect to the Sub-Criteria of *Usability*

			Round 1			Round 2
Sub-Criteria	IQR	Median	Level of Consensus	IQR	Median	Level of Consensus
Understandability	1	4	Good Consensus	1	4	Good Consensus
Learnability	1	4	Good Consensus	1	5	Good Consensus
Operability	2	4	Moderate Consensus	1	4	Good Consensus
Customizability	1	4	Good Consensus	1	4	Good Consensus
Hypermediality	1	4	Good Consensus	1	4	Good Consensus
Support Tools	1	4	Good Consensus	1	4	Good Consensus
Presentation	1	4	Good Consensus	1	4	Good Consensus
Learner Interface	2	4	Moderate Consensus	2	4	Moderate Consensus
Learning Content	0	4	High Consensus	0	4	High Consensus
Accessibility Control (New Sub-Criteria)	-	-	-	***0***	***4***	***High Consensus***

5.3.3.4 The Consensus Among Experts With Respect to the Sub-Criteria of *Reliability*

Table 5.9 shows the consensus among experts, based on the IQR and Median score, for each sub-criterion of the *Reliability* evaluation criteria. After Round 2, two criteria encompassing *Fault Tolerance* and *Backup and Recovery* obtained a Good Consensus with the IQR value of 1. One sub-criterion of *Maturity* obtained a Moderate Consensus with the IQR value of 2. The result showing the level of the experts' consensus for the sub- criteria of *Maturity* obtained a consistent consensus where the same value of the IQR was obtained for both rounds. The IQR value was between Moderate Consensus (*IQR = 2*) and Good Consensus (*IQR = 1*). Nonetheless, the statistics also showed that there was an improvement among the experts in their consensus for the sub criteria of *Fault Tolerance* and *Backup and Recovery* where the consensus obtained was from Moderate Consensus (*IQR = 2* in Round One) to Good Consensus (*IQR = 1* in Round Two). One additional sub-criterion of *Error reporting* showed a High Consensus. After Round 2, the Median result for each sub-criterion of the *Reliability* evaluation criteria showed a Median value of 4. Therefore, all the 4 sub-criteria for *Reliability* were accepted as the Median values were not less than 3.5, as explained by Ononiwu (2013) and Pichlack (2015).

Table 5.9: Consensus Among Experts With Respect to the Sub-Criteria of *Reliability*

	Round 1			Round 2		
Sub-Criteria	IQR	Median	Level of Consensus	IQR	Median	Level of Consensus
Maturity	2	4	Moderate Consensus	2	4	Moderate Consensus
Fault Tolerance	2	4	Moderate Consensus	1	4	Good Consensus
Backup and Recovery	2	4	Moderate Consensus	1	4	Good Consensus
Error Reporting (New Sub-Criteria)	-	-	-	***0***	***4***	***High Consensus***

5.3.3.5 The Consensus Among Experts With Respect to the Sub-Criteria of *Portability*

Table 5.10 shows the consensus of the experts, based on the IQR and Median score, for each sub-criterion under the *Portability* evaluation criteria. After Round 2, five sub-criteria encompassing: *Adaptability*, *Installability*, *Replaceability*, *DBMS Standard* and *Middleware Standard* obtained a Good Consensus with the IQR value of 1. The result for the level of expert consensus showed that the sub-criteria of *Adaptability, Installability*, *Replaceability*, *DBMS Standard* and *Middleware Standard* obtained a consistent consensus where the same value of the IQR (*IQR = 1*) was obtained for both rounds. Results also indicate that there was an improvement among the experts in their consensus for the sub-criteria of *Conformance* which obtained Good Consensus (*IQR = 1* in Round 1) to High Consensus (*IQR = 0* in Round 2). One additional sub-criterion of *Standardability* obtained Good Consensus (*IQR =1* in Round 2). There was also an improvement in the Median value (from *Median Value = 3* in Round 1 to *Median Value = 4* in Round 2) for *Replaceability*. This shows that the number of experts who agreed with the *Replaceability* sub-criteria had increased. After Round 2, the Median result for each sub-criterion of *Portability* showed the Median value of 4.

Therefore, all the seven sub-criteria for *Portability* were accepted as the Median values were not less than 3.5, as explained by Ononiwu (2013) and Pichlack (2015).

Table 5.10: Consensus Among Experts With Respect to the Sub-Criteria of *Portability*

	Round 1			Round 2		
Sub-Criteria	IQR	Median	Level of Consensus	IQR	Median	Level of Consensus
Adaptability	1	4	Good Consensus	1	4	Good Consensus
Installability	1	4	Good Consensus	1	4	Good Consensus
Replaceability	1	3	Good Consensus	1	4	Good Consensus
Conformance	1	4	Good Consensus	0	4	High Consensus
DBMS Standard	1	4	Good Consensus	1	4	Good Consensus
Middleware Standard	1	4	Good Consensus	1	4	Good Consensus
Standardability (New Sub-Criteria)	-	-	-	***1***	***4***	***Good Consensus***

5.3.3.6 The Consensus Among Experts With Respect to the Sub-Criteria of *Efficiency*

Table 5.11 shows the consensus among experts, based on the IQR and Median score, for each sub-criterion of *Efficiency*. After Round 2, all the three sub-criteria encompassing: *Time Behaviour, Resource Behaviour* and *Memory Capacity* obtained a High Consensus with the IQR value of 0. This result for the level of expert consensus shows that the sub-criteria of *Resource Behaviour* and *Memory Capacity* obtained a consistent consensus where the same IQR value was obtained for both rounds. The IQR value for *Resource Behaviour* and *Memory Capacity* obtained in Round 1 and Round 2 was 0. There was also an improvement in the consensus among the experts for the sub-criterion of *Time Behaviour* which obtained Good Consensus (*IQR =1* in Round 1) to High Consensus (*IQR = 0* in Round 2). After Round 2, the Median result for each sub-criterion of *Efficiency* showed the Median value of 4. Therefore, all the three sub-criteria for *Efficiency* were accepted as the Median values were not less than 3.5, as explained by Ononiwu (2013) and Pichlack (2015).

Table 5.11: Consensus Among Experts With Respect to the Sub-Criteria of *Efficiency*

	Round 1			Round 2		
Sub-Criteria	IQR	Median	Level of Consensus	IQR	Median	Level of Consensus
Time Behavior	1	4	Good Consensus	0	4	High Consensus
Resource Behavior	0	4	High Consensus	0	4	High Consensus
Memory Capacity (New Sub-Criteria)	***0***	***4***	***High Consensus***	***0***	***4***	***High Consensus***

5.3.3.7 The Consensus Among Experts With Respect to the Sub-Criteria of *Cost*

Table 5.12 shows the consensus among experts, based on the IQR and Median score, for each sub-criterion under the *Cost* evaluation criteria. After Round 2, six sub-criteria encompassing: *Licensing Cost*, *Implementation Cost*, *Maintenance Cost*, *Upgrade Cost*, *Training Cost* and *Marginal Cost* obtained Good Consensus with the IQR value of 1. Two sub-criteria of *Development Cost* and *Hardware Cost* obtained Moderate Consensus with the IQR value of 2. The IQR value was between Moderate Consensus (*IQR = 2*) and Good Consensus (*IQR = 1*).

There was also an improvement among the experts in their consensus for the *Training Cost* sub-criteria which obtained Moderate Consensus (*IQR = 2* in Round 1) to Good Consensus (*IQR = 1* in Round 2). One additional sub-criterion of *Marginal Cost* obtained Good Consensus. After Round 2, the Median result for each sub-criterion of *Cost* showed the Median value of 4. Therefore, all the seven sub-criteria for *Cost* were accepted as the Median values were not less than 3.5, as explained by Ononiwu (2013) and Pichlack (2015).

Table 5.12: Consensus Among Experts With Respect to the Sub-Criteria of *Cost*

	Round 1			Round 2		
Sub-Criteria	IQR	Median	Level of Consensus	IQR	Median	Level of Consensus
Licensing Cost	1	4	Good Consensus	1	4	Good Consensus
Development Cost	2	4	Moderate Consensus	2	4	Moderate Consensus
Implement Cost	1	4	Good Consensus	1	4	Good Consensus
Maintenance Cost	1	4	Good Consensus	1	4	Good Consensus
Upgrade Cost	1	4	Good Consensus	1	4	Good Consensus
Hardware Cost	2	4	Moderate Consensus	2	4	Moderate Consensus
Training Cost	2	4	Moderate Consensus	1	4	Good Consensus
Marginal Cost (New Sub-Criteria)	-	-		***1***	***4***	***Good Consensus***

5.3.3.8 The Consensus Among Experts With Respect to the Sub-Criteria of *Vendor*

Table 5.13 shows the consensus among experts, based on the IQR and Median score, for the sub-criterion of *Vendor*. After Round 2, two sub-criteria encompassing: *Reputation and Training* obtained a High Consensus with the IQR value of 0. Eight sub-criteria of *Services, User manual, Troubleshooting Guide, Maintenance and Upgrading, Communication, Demo, Technical and Business Skills* and *Past Business Experience* obtained Good Consensus with the IQR value of 1. The four sub-criteria of *Support and Consultancy, Tutorial, Response Time and Length of Experience* obtained a Moderate Consensus with the IQR value of 2. The result for the level of expert consensus showed that the sub-criteria of *Support and Consultancy, Tutorial, Troubleshooting Guide, Maintenance and Upgrading, Communication, Demo, Response time, Length of Experience, Technical Business Skills* and *Past Business Experience* obtained a consistent consensus where the same value of the IQR was obtained for both rounds. The IQR value was Moderate Consensus (*IQR = 2*), Good Consensus (*IQR = 1*) and High Consensus (*IQR = 0*).

There was also an improvement among the experts' consensus for *Reputation* sub-criterion, from Good Consensus (*IQR = 1* in Round 1) to High Consensus (*IQR = 0* in Round 2). Likewise, there was also an improvement among the experts' consensus for *Services* sub-criterion, from Moderate Consensus (IQR = 2 in Round 1) to Good Consensus (*IQR = 1* in Round 2). The sub-criterion of *User manual* obtained a Moderate (*IQR = 2* in Round 1) to Good Consensus (*IQR = 1* in Round Two) while the *Training* sub-criterion obtained a Good Consensus (*IQR = 1* in Round 1) to High Consensus (*IQR = 0* in Round 2). There were no additional criteria received for *Vendor*. This shows that the experts agreed with the available sub-criteria extracted from literature. After Round 2, the Median result for each sub-criteria of *Vendor* showed the Median value of 4. Therefore, all the 14 sub-criteria for *Vendor* were accepted as the Median values were not less than 3.5, as explained by Ononiwu (2013) and Pichlack (2015).

Table 5.13: Consensus Among Experts With Respect to the Sub-Criteria of *Vendor*

	Round 1			**Round 2**		
Sub-Criteria	IQR	Median	Level of Consensus	IQR	Median	Level of Consensus
Reputation	1	4	Good Consensus	0	4	High Consensus
Support and Consultancy	2	4	Moderate Consensus	2	4	Moderate Consensus
Services.	2	4	Moderate Consensus	1	4	Good Consensus
User Manual	2	4	Moderate Consensus	1	4	Good Consensus
Tutorial	2	4	Moderate Consensus	2	4	Moderate Consensus
Troubleshooting Guide	1	4	Good Consensus	1	4	Good Consensus
Training	1	4	Good Consensus	0	4	High Consensus
Maintenance and Upgrading	1	4	Good Consensus	1	4	Good Consensus
Communication	1	4	Good Consensus	1	4	Moderate Consensus
Demo	1	4	Good Consensus	1	4	Good Consensus
Response Time	2	4	Moderate Consensus	2	4	Moderate Consensus
Length of Experience	2	4	Moderate Consensus	2	4	Moderate Consensus
Technical and Business Skills	1	4	Good Consensus	1	4	Good Consensus
Past Business Experience	1	4	Good Consensus	1	4	Good Consensus

5.3.3.9 The Consensus Among Experts With Respect to the Sub-Criteria of *Organizational*

Table 5.14 shows the consensus among experts, based on the IQR and Median score, for each sub-criterion under the *Organizational* evaluation criteria. After Round 2, four sub-criteria encompassing: *Organizational Culture, Organizational Resource, Organizational Change* and *Resource and Organization Politic* obtained Good Consensus with the IQR value of 1. There was also an improvement on the Median value from (*Median Value = 3* in Round 1) to (*Median Value = 4* in Round 2) for *Organizational Resource*. This shows that the number of experts who agreed with the *Organizational Resource* sub-criteria had increased. After Round 2, the Median result for each sub-criterion of the *Organizational* evaluation criteria showed the Median value of 4. However, for the sub-criterion of *User Acceptance*, the Median result was less than 3.5, as explained by Ononiwu (2013) and Pichlack (2015). This criterion did not obtain the experts' consensus as the Median gained from the experts equalled to 3. This shows that the experts in this study did not consider the *User Acceptance* criterion as an important factor in the evaluation of the e-LS. Therefore, it was rejected from the e-LS sub-criteria list. The other four sub-criteria encompassing the *Organizational Culture, Organizational Resource, Organizational Change* and *Organization Politic* were accepted.

Table 5.14: Consensus Among Experts With Respect to the Sub-Criteria of *Organizational*

	Round 1			**Round 2**		
Sub-Criteria	IQR	Median	Level of Consensus	IQR	Median	Level of Consensus
Organizational Culture	1	4	Good Consensus	1	4	Good Consensus
Organizational Resource	1	3	Good Consensus	1	4	Good Consensus
Organizational Change	1	4	Good Consensus	1	4	Good Consensus
Organizational Politics	1	4	Good Consensus	1	4	Good Consensus
User Acceptance	1	3	Good Consensus	1	3	Good Consensus

5.3.3.10 The Consensus Among Experts With Respect to the Sub-Criteria of *Product Benefit*

Table 5.15 shows the consensus among the experts, based on the IQR and Median score, for each sub-criterion encompassing the *Product Benefit* evaluation criteria. After Round 2, the result for the level of the experts' consensus showed that the sub-criteria of *User Satisfaction* and *Ease of Use* obtained a consistent consensus where the same value of the IQR was obtained for both rounds. There were three sub-criteria added by the experts under the *Product Benefit* Criteria. One sub-criterion of *User Productivity,* obtained a High Consensus, one sub-criterion of *Cost Saving,* obtained a Moderate Consensus and one sub-criterion of *After Sales Services* obtained a Good Consensus. After Round 2, the Median result for each sub-criterion of the *Product Benefit* evaluation criteria showed the Median value of 4. Therefore, all the five sub-criteria for *Product Benefit* were accepted as the Median values were not less than 3.5, as explained by Ononiwu (2013) and Pichlack (2015).

Table 5.15: Consensus Among Experts With Respect to the Sub-Criteria of *Product Benefit*

	Round 1			**Round 2**		
Sub-Criteria	IQR	Median	Level of Consensus	IQR	Median	Level of Consensus
User Satisfaction	2	4	Moderate Consensus	2	4	Moderate Consensus
Ease of use	2	4	Moderate Consensus	2	4	Moderate Consensus
User Productivity (New sub-Criteria)	-	-	-	0	4	High Consensus
Cost Saving (New Sub-Criteria)	-	-	-	2	4	Moderate Consensus
After Sales Service (New Sub-Criteria)	-	-	-	1	4	Good Consensus

5.3.3.11 The Consensus Among Experts With Respect to the Sub-Criteria of *Risk and Uncertainty*

Table 5.16 shows the consensus among experts, based on the IQR and Median score, for each sub-criterion under *Risk and Uncertainty*. After Round 2, one sub-criterion of *Vendor Risk*, obtained a Good Consensus with the IQR value of 1. Two sub-criteria of

Product Risk and *Software Bugs*, obtained a Moderate Consensus with the IQR value of 2. All the four additional sub-criteria of *Frequency of Software Release*, *Virus and SPAM*, *Unexpected Cost* and *Educational Systems Changed* obtained a Good Consensus. After Round 2, the Median result for each sub-criterion of *Risk and Uncertainty* showed the Median value of 4. Therefore, all the seven sub-criteria for *Risk and Uncertainty* were accepted as the Median values were not less than 3.5, as explained by Ononiwu (2013) and Pichlack (2015).

Table 5.16: Consensus Among Experts With Respect to the Sub-Criteria of *Risk and Uncertainty*

	Round 1			Round 2		
Sub-Criteria	IQR	Median	Level of consensus	IQR	Median	Level of consensus
Vendor Risk	1	4	Good Consensus	1	4	Good Consensus
Product Risk	2	4	Moderate Consensus	2	4	Moderate Consensus
Software Bugs	2	4	Moderate Consensus	2	4	Moderate Consensus
Frequency of Software Release (New Sub-Criteria)	-	-		*1*	*4*	*Good Consensus*
Virus and SPAM (New Sub-Criteria)	-	-		*1*	*4*	*Good Consensus*
Unexpected Cost (New Sub-Criteria)	-	-		*1*	*4*	*Good Consensus*
Educational System Changed (New Sub-Criteria)	-	-		*1*	*4*	*Good Consensus*

5.3.4 Summary of the Experts' Consensus Towards the Evaluation Criteria and the Sub-Criteria for the e-LS

The following is a summary of the results of the experts' consensus for the 66 sub-criteria identified from literature and the 16 sub-criteria added by the experts. From the initial 66 sub-criteria identified in the literature, eight had achieved a High Consensus, 44 had obtained a Good Consensus and the remaining 15 had obtained a Moderate Consensus. All but one sub-criterion were accepted. The sub-criterion, which fell under the *Organizational* criterion was rejected because its Median value was less than 3.5. Therefore, from the Delhi survey conducted, a total of 66 sub-criteria were accepted by the experts. Table 5.17 lists the criteria and the respective number of sub-criteria that were identified from the literature and the level of consensus obtained for each.

Table 5.17: Criteria and Sub-Criteria Identified in Literature

Factors	Criteria	Number of sub-criteria	Level of consensus
SQM	*Efficiency*	2	High Consensus
SQM	*Maintainability*	1	High Consensus
SQM	*Portability*	1	High Consensus
SQM	*Reliability*	1	High Consensus
SQM	*Usability*	1	High Consensus
COTS	*Vendor*	2	High Consensus
	SUB TOTAL	8	
COTS	*Cost*	5	Good Consensus
SQM	*Functionality*	8	Good Consensus
SQM	*Maintainability*	4	Good Consensus
COTS	*Organizational*	4 + (1 rejected)	Good Consensus
SQM	*Portability*	5	Good Consensus
SQM	*Reliability*	2	Good Consensus
COTS	*Risk and Uncertainty*	1	Good Consensus
SQM	*Usability*	7	Good Consensus
COTS	*Vendor*	7	Good Consensus
	SUB TOTAL	44	
COTS	*Cost*	2	Moderate Consensus
SQM	*Functionality*	1	Moderate consensus
SQM	*Maintainability*	1	Moderate consensus
COTS	*Product Benefit*	2	Moderate Consensus
SQM	*Reliability*	1	Moderate Consensus
COTS	*Risk and Uncertainty*	2	Moderate Consensus
SQM	*Usability*	1	Moderate Consensus
COTS	*Vendor*	5	Moderate Consensus
	SUBTOTAL	15	
	TOTAL ACCEPTED	66	

Besides identifying the sub-criteria from the literature review, an additional 16 sub-criteria were added as a result of the Delphi survey administered on the 31 experts. The additional sub-criteria were added to all the evaluation criteria except for *Organizational* and *Vendor*. Table 5.18 shows the list of the expert's added sub-criteria and the level of consensus among them.

Table 5.18: Sub-Criteria Added by Experts

Factors	Criteria	Experts' added sub-criteria	Level of consensus
SQM	*Efficiency*	*Memory Capacity*	High Consensus
SQM	*Functionality*	*User/Learner Administration*	High Consensus
SQM	*Maintainability*	*Expansion*	High Consensus
COTS	*Product Benefit*	*User Productivity*	High Consensus
SQM	*Reliability*	*Error Reporting*	High Consensus
SQM	*Usability*	*Accessibility Control*	High Consensus
COTS	*Cost*	*Marginal Cost*	Good Consensus
SQM	*Maintainability*	*Error Preventing*	Good Consensus
SQM	*Maintainability*	*Fault Software*	Good Consensus
SQM	*Portability*	*Standardability*	Good Consensus
COTS	*Product Benefit*	*After Sales Service*	Good Consensus
COTS	*Risk and Uncertainty*	*Educational System Changed*	Good Consensus
COTS	*Risk and Uncertainty*	*Frequency of Software Release*	Good Consensus
COTS	*Risk and Uncertainty*	*Unexpected Cost*	Good Consensus
COTS	*Risk and Uncertainty*	*Virus and SPAM*	Good Consensus
COTS	*Product Benefit*	*Cost Saving*	Moderate Consensus
COTS	*Vendor*	-	-
COTS	*Organizational*	-	-

These 16 sub-criteria provided by the experts had obtained either a High Consensus, a Good Consensus or a Moderate Consensus with the IQR value of 2 in the final round of the Delphi Survey. Six sub-criteria had received a High Consensus, nine had achieved a Good Consensus and only one sub-criterion had obtained a Moderate Consensus. These sub-criteria were also accepted as all their Median values were greater than 3.5. These results indicate that there were other valid sub-criteria to be considered in an e-LS evaluation besides those identified from the literature. Out of the 16 sub-criteria obtained from the Delphi Survey, eight sub-criteria were from COTS and eight sub-criteria were from the SQM factors. Both these two additional sets of sub-criteria detected from the COTS and SQM, need to be included in the evaluation of the e-LS. Doing so would allow the respective organizations to have a more comprehensive list of criteria and sub-criteria which can be used for the e-LS evaluation.

Overall, the results from the data analysis showed that 15.85% of the sub-criteria had achieved a High Consensus among the experts; 64.63% of the sub-criteria had obtained a Good Consensus and 19.51% of the sub-criteria had received a Moderate Consensus. It was further noted that the additional sub-criteria which were obtained from the experts' opinions, tend to achieve a Good to High Consensus. This may indicate the importance of seeking the experts' opinions when considering any evaluation process. It appears that such a process involving the experts' input should be taken into account when evaluating and selecting the e-LS as their opinions are more practical based as compared to literature which may be more theoretical based. Figure 5.1 shows the breakdown of the sub-criteria based on experts' consensus.

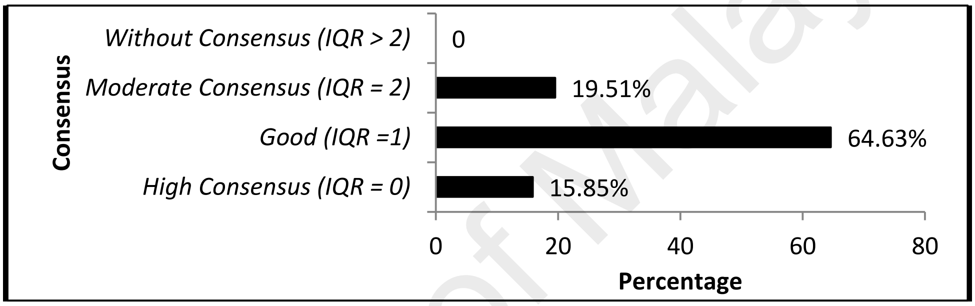


Figure 5.1: Experts' Consensus Breakdown of the Sub-Criteria

5.3.5 Priority Ranking of the e-LS Evaluation Criteria by Experts

In this ection the results of the priority ranking of the evaluation criteria made by the experts are presented separately before the overall results of the three groups are illustrated.

5.3.5.1 Evaluation Criteria Ranked by Technical Experts

Results obtained from the Technical Experts showed that out of 11 criteria, 10 evaluation criteria were ranked Important and one criterion was ranked Moderately Important. The top three most important evaluation criteria include *Functionality* (rank 1), *Efficiency* (rank 2) and *Usability* (rank 3). This is followed by *Reliability* (rank 4), *Maintainability* (rank 5), *Cost* (rank 6), *Portability* (rank 7), *Product Benefit* (rank 8), *Vendor* (rank 9) and *Risk and Uncertainty* (rank 10). The *Organizational* criterion ranked last; it was considered as Moderately Important by the Technical Experts. Table 5.19 shows the priority of the criteria based on the ranking made by the Technical Experts.

Table 5.19: Evaluation Criteria of e-LS Ranked by Technical Experts

	Round 1	N=11	Round 2	N=11		
Criteria	**Mean Average**	**Std Dev Average**	**Mean Average**	**Std Dev Average**	**Scale**	**Rank**
Functionality	4.051	0.728	4.191	0.634	Important	1
Efficiency	4.000	0.620	4.12	0.494	Important	2
Usability	3.969	0.796	4.109	0.604	Important	3
Reliability	4.030	0.736	4.091	0.622	Important	4
Maintainability	3.939	0.714	4.000	0.627	Important	5
Cost	3.935	0.584	3.932	0.631	Important	6
Portability	3.788	0.621	3.818	0.614	Important	7
Product Benefit	3.636	0.662	3.855	0.576	Important	9
Vendor	3.526	0.662	3.681	0.611	Important	9
Risk and Uncertainty	3.576	0.948	3.623	0.724	Important	10
Organizational	3.327	0.680	3.455	0.625	Moderately Important	11

The results revealed that the Technical Experts agreed that all the criteria identified in this survey were important to be included in the evaluation and selection process of the e-LS.

5.3.5.2 Evaluation Criteria Ranked by Decision Makers

The result from the Decision Makers revealed that nine evaluation criteria were ranked as Extremely Important and two evaluation criteria were ranked as Important. The top three criteria ranked as Extremely Important include *Reliability* (rank 1), *Functionality* (rank 2) and *Vendor* (rank 3). This is followed by *Maintainability* (rank 4), *Cost* (rank 5), *Usability* (rank 6), *Risk and Uncertainty* (rank 7) *Product Benefit* (rank 8). The final three evaluation criteria ranked Important include *Efficiency* (rank 9), *Organizational* (rank 10) and *Portability* (rank 11). Table 5.20 shows the priority of the evaluation criteria as ranked by the Decision Makers.

Table 5.20: The Priority of Evaluation Criteria Ranked by Decision Makers

	Round 1	N=10	Round 2	N=10		
Criteria	**Mean Average**	**Std Dev Average**	**Mean Average**	**Std Dev Average**	**Scale**	**Rank**
Reliability	4.367	0.837	4.5	0.490	Extremely Important	1
Functionality	4.267	0.744	4.42	0.645	Extremely Important	2
Vendor	4.136	0.863	4.329	0.727	Extremely Important	3
Maintainability	4.267	0.724	4.256	0.521	Extremely Important	4
Cost	4.129	0.723	4.213	0.654	Extremely Important	5
Usability	4.133	0.766	4.21	0.686	Extremely Important	6
Risk and Uncertainty	3.967	0.815	4.143	0.787	Extremely Important	7
Product Benefit	3.95	0.777	4.120	0.675	Extremely Important	8
Efficiency	4.000	0.742	4.03	0.539	Extremely Important	9
Organizational	3.8	0.811	3.9	0.683	Important	10
Portability	3.683	0.854	3.714	0.799	Important	11

5.3.5.3 Evaluation Criteria Ranked by Academicians/Researchers

Out of the 11 evaluation criteria ranked by the Academicians/Researchers, the result showed that nine criteria were ranked Important, one criterion was ranked Extremely Important and one criterion was ranked Moderately Important. *Functionality* (rank 1) was ranked Extremely Important. The other important evaluation criteria encompassed *Product Benefit* (rank 2), *Usability* (rank 3), *Vendor* (rank 4), *Efficiency* (rank 5), *Cost* (rank 6), *Maintainability* (rank 7), *Portability* (rank 8), *Risk and Uncertainty* (rank 9) and *Reliability* (rank 10) was ranked as Important. The *Organizational* criterion was ranked the lowest (rank 11) as Moderately Important. Table 5.21 shows the priority of the evaluation criteria as ranked by the Academicians /Researchers.

Table 5.21: The Priority of Evaluation Criteria Ranked by Academicians/Researchers

	Round 1	N=10	Round 2	N=10		
Criteria	**Mean Average**	**Std Dev Average**	**Mean Average**	**Std Dev Average**	**Scale**	**Rank**
Functionality	3.944	0.860	4.090	0.753	Extremely Important	1
Product Benefit	3.900	0.875	3.960	0.808	Important	2
Usability	3.767	0.781	3.940	0.745	Important	3
Vendor	3.707	0.803	3.793	0.758	Important	4
Efficiency	3.700	0.981	3.767	0.642	Important	5
Cost	3.771	0.899	3.763	0.809	Important	6
Maintainability	3.700	0.910	3.733	0.728	Important	7
Portability	3.500	0.623	3.714	0.5662	Important	8
Risk and Uncertainty	3.567	0.749	3.629	0.728	Important	9
Reliability	3.467	0.628	3.550	0.589	Important	10
Organizational	3.420	0.697	3.460	0.619	Moderately Important	11

Based on the results, it appears that *Functionality* was considered as the Most Important criteria for the e-LS evaluation by Technical Experts and Academicians/Researchers. In contrast, the Decision Makers were more concerned about the sub-criterion of *Reliability* for the e-LS evaluation. Both of these criteria were listed in the SQM.

It was also noted that the experts had agreed on the *Organizational* criterion which was ranked lowly by the experts. It was ranked 11 by the Technical Experts and the Academicians/Researchers but it was ranked 10 by the Decision Makers. Based on this, it can be deduced that in terms of ranking, the Decision Makers and the Technical Experts in this study were not concerned about the *Organizational* criterion for the e-LS evaluation.

However, the overall result showed that in general, the experts agreed that the *Organizational* criterion was important even though it was ranked the lowest. As to the construct of the ISQM, the *Organizational* criterion and each of its sub-criterion except *User Acceptance*, were included in the Delphi Survey.

5.3.5.4 The Overall Ranking Results Made by the Experts

The overall ranking of the criteria made by the 31 experts showed that the criteria could be ranked as Important or Highly Important. From the 11 criteria identified from the literatures, the criterion of *Functionality* was ranked as the Most Important criteria. Table 5.22 summarizes the criteria ranking made by all the experts.

Table 5.22: The Priority of Evaluation Criteria Ranked by All 31 Experts

	Round 1 N=31		**Round2 N= 31**			
Criteria	**Mean Average**	**Std Dev Average**	**Mean Average**	**Std Dev Average**	**Rank**	**Scale**
Functionality	4.104	0.777	4.232	0.701	1	Extremely Important
Usability	4.018	0.749	4.087	0.682	2	Extremely Important
Reliability	3.989	0.828	4.056	0.684	3	Extremely Important
Maintainability	3.989	0.801	3.996	0.668	4	Important
Efficiency	3.903	0.786	3.978	0.569	5	Important
Product Benefit	3.855	0.769	3.974	0.687	6	Important
Cost	3.959	0.739	3.968	0.715	7	Important
Vendor	3.809	0.798	3.929	0.752	8	Important
Portability	3.672	0.706	3.751	0.669	9	Important
Risk and Uncertainty	3.709	0.849	3.793	0.768	10	Important
Organizational	3.509	0.747	3.6	0.653	11	Important

Based on the mean average, it was noted that no criteria was ranked as Moderately Important, Unimportant or Strongly Unimportant. Three evaluation criteria of *Functionality*, *Usability* and *Reliability* were ranked as Extremely Important. The remaining eight evaluation criteria of *Maintainability, Portability, Efficiency, Product Benefit, Cost, Vendor, Risk and Uncertainty,* and *Organizational* were ranked as Important. Therefore, these evaluation criteria should be taken into consideration in the evaluation of the e-LS.

5.4 The Construction of an Integrated Software Quality Model (ISQM) for the e-LS Evaluation

The ISO/IEC 9126-1 Quality Model was used as a basis to construct the ISQM for the e-LS evaluation. Figure 5.2 illustrates the ISO/IEC 9126-1 Quality Model which consists of six evaluation criteria that are used for the evaluation of the software products.

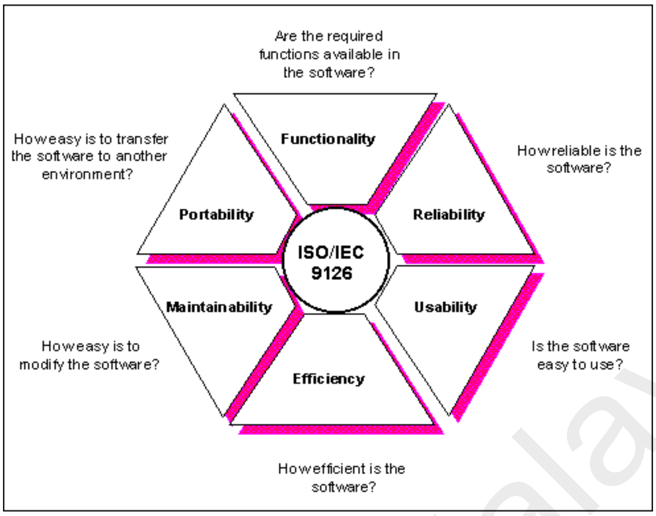


Figure 5.2: ISO/IEC 9126-1 Quality Model

In total, 11 main criteria were identified for the construction of the ISQM. The six criteria listed were taken from the ISO/IEC 9126-1 Quality Model. The criteria includes *Functionality*, *Usability*, *Maintainability*, *Efficiency*, *Portability* and *Reliability*. These were integrated with another five criteria taken mainly from the COTS evaluation framework and they include Cost, *Vendor*, *Product Benefits*, *Risk and Uncertainty* and *Organizational*. The review of literature was able to extract 66 sub-criteria from selected articles as depicted in Table 5.2. All were validated by the experts' consensus as noted in the Delphi Survey which provided an additional 16 sub-criteria. One sub-criterion was rejected as it did not achieve the experts' consensus. Altogether, there were eleven (11) main criteria and 81 sub criteria used in the construction of the ISQM. The ISQM for the e-LS evaluation is shown in Figure 5.3. The abbreviations and definitions used for the criteria and sub-criteria are illustrated in Appendix F.

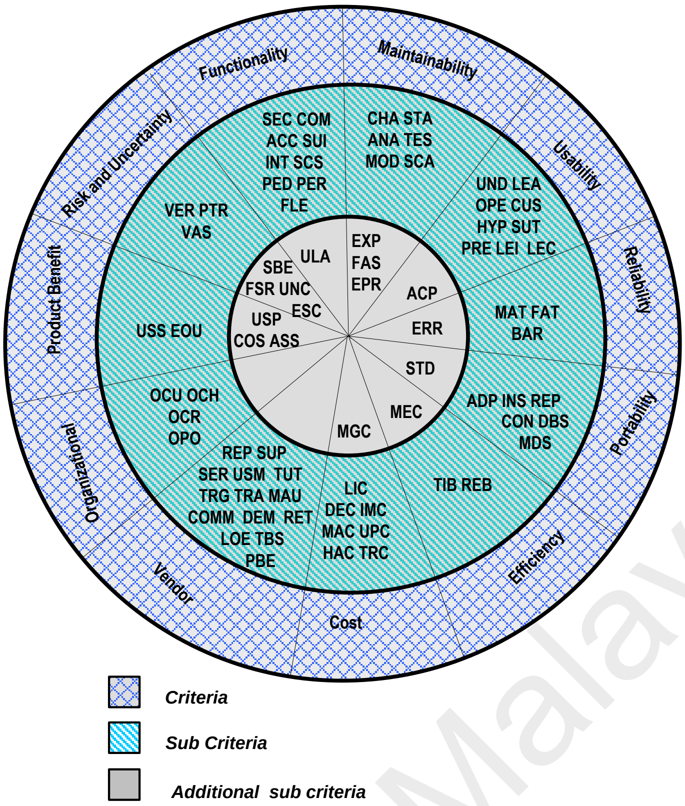


Figure 5.3: ISQM for e-LS Evaluation

The ISO/IEC 9126-1 Quality Model was further refined into sub characteristics which in turn, were decomposed into attributes thereby, yielding a multilevel hierarchy (Franch & Carvallo, 2003). Figure 5.4 shows the hierarchical structure of the ISO/IEC 9126-1 Quality Model.

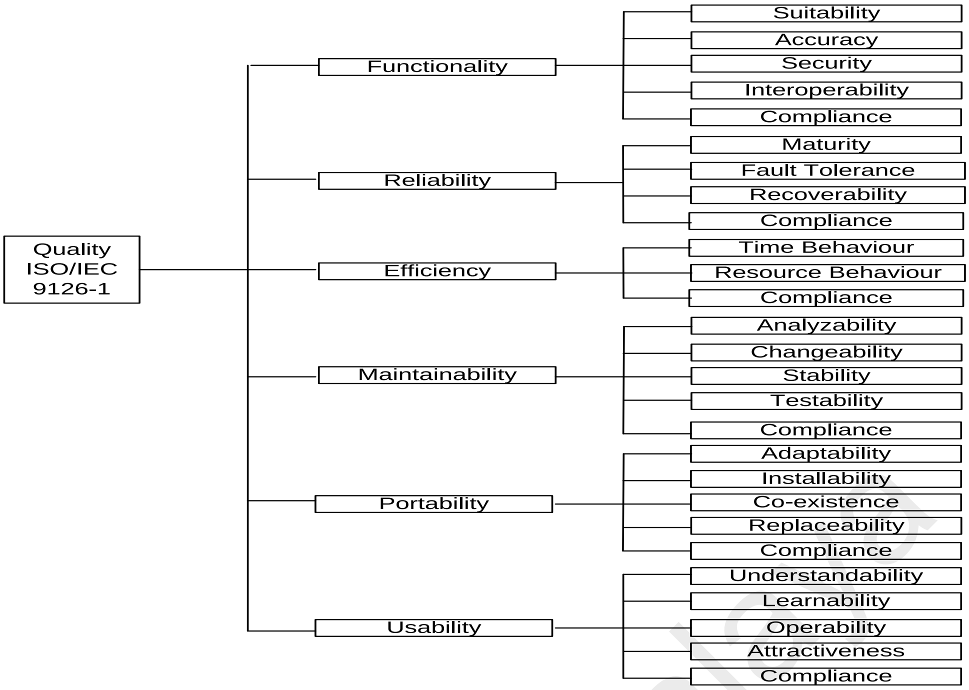


Figure 5.4: Hierarchical Structure of ISO/IEC 9126-1 Quality Model for Software Product Evaluation (Samadhiya et al., 2010)

Similar to the above, the ISQM for evaluating the e-LS was further refined into the hierarchical structure. The 11 main criteria and 81 sub criteria used for the e-LS were decomposed into the hierarchical structure as illustrated in Figure 5.5.

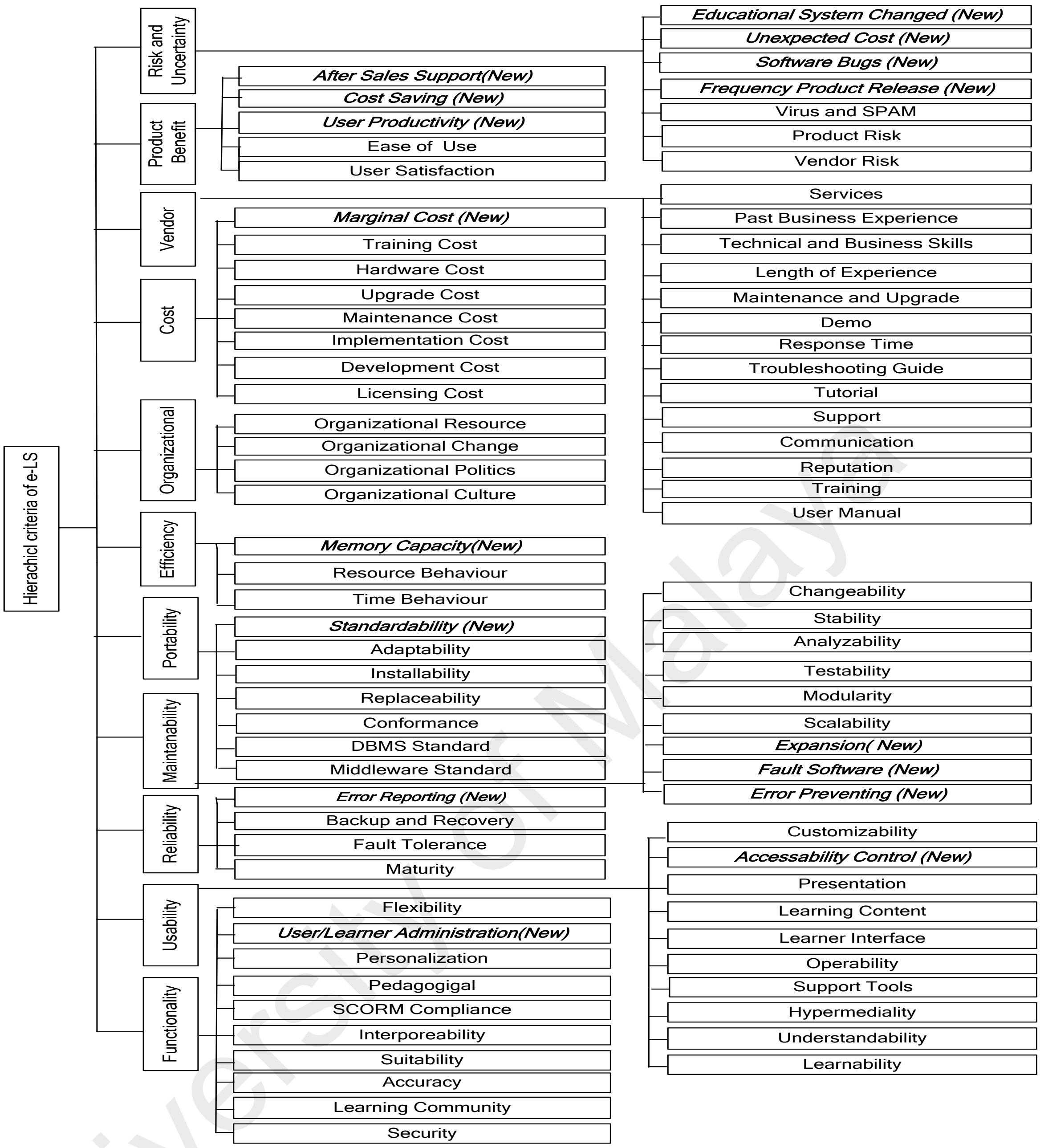


Figure 5.5: Hierarchical Structure for the e-LS Evaluation Criteria and Sub-Criteria of the ISQM

The main criteria and sub-criteria used in the construction of the ISQM were based on the Delphi study that was conducted before 2011. In 2011, the ISO/IEC 25010 was released and then reviewed (see page 43). The ISO/IEC 25010 was constructed for the purpose of evaluating the software products (ISO/IEC 25010, 2011). The criteria and sub-criteria extracted from the ISO9126-1 were revised and then used as the basic foundation to construct the ISO 25010 (Lew et al., 2010). In this regard, some criteria and sub-criteria noted in the ISO/IEC 25010 and the ISQM may be similar. Some of the criteria included in the ISO/IEC 25010 such as *Functionality, Reliability, Portability* and *Efficiency* have already been covered in the ISQM. Meantime, other sub-criteria of the ISO/IEC 25010 such as *Maturity, Recoverability* and *Fault Tolerance* which come under the *Reliability* criterion and the sub-criteria of *Learnability* and *Operability* under the *Usability* criterion as well as the sub-criteria of *Modularity, Analysability* and *Testability* under the *Maintainability* criterion were also noted in the ISQM. The sub-criteria of *Adaptability*, *Installability* and *Replaceability* under the *Portability* criterion were further listed in the ISQM.

The difference between the ISQM and the ISO/IEC25010 is the categorisation of the criteria and sub criteria. For example, the sub-criteria of *Security* was found as a separate criterion in the ISO/IEC 25010 rather than as a sub-criterion of *Functionality* in the ISO/IEC 9126-1 and ISQM. This difference enhances the descriptiveness of the *Security* criterion in the ISO/IEC 25010 (Lew at al., 2010). The other difference between the ISQM and the ISO/IEC 25010 is the applicability of the models. As mentioned in page 44, the Quality Model of the ISO/IEC 25010 is applicable to both computer systems and the software products (ISO/IEC 25010, 2011). The Quality Model of the ISO/IEC 25010 is applicable for the human-computer system and the software products in use. Therefore, some criteria listed in the ISO/IEC 25010 may be different from those in the ISQM in terms of the applicability of the models. Likewise, as the ISQM was constructed for the purpose of evaluating the e-LS, some criteria of the ISQM may not be listed in the ISO/IEC 25010. The criteria and sub-criteria of the ISQM are more comprehensive in terms of supporting the evaluation of the e-LS as compared to the ISO/IEC 25010. The comparison between the ISQM and ISO/IEC 25010 is projected in Table 5.23.

Table 5.23: Comparison Between ISQM and ISO/IEC 25010

ISQM		ISO/IEC 25010	
		i. Product Quality	**Model Of ISO/IEC 25010**
Criteria	**Sub-Criteria**	**Criteria**	**Sub-Criteria**
Functionality	Suitability	Functionality Suitability	Functional Completeness
	Accuracy		Functional Correctness
	Flexibility		Functional Appropriateness
	Security	Reliability	Maturity
	Interoperability		Availability
	Pedagogical		Fault Tolerance
	Personalization		Recoverability
	Community	Performance Efficiency	Time Behaviour
	SCORM Compliance		Resource Utilisation
	User/Learner Administration		Capacity
Maintainability	Changeability	Usability	Appropriateness Recognisability
	Stability		Learnability
	Analyzability		Operability
	Testability		User Error Protection
	Modularity		User Error Protection
	Scalability		User Interface Aesthetics
	Expansion		Accessibility
	Fault Software	Maintainability	Modularity
	Error Preventing		Reusability
Reliability	Maturity		Analysability
	Fault Tolerance		Modifiability
	Backup and Recovery		Testability
	Error Reporting	Security	Confidentiality
Usability	Understandability		Non-Repudiation
	Learnability		Acoountability
	Operability		Authenticity
	Customizability	Compatibility	Co-existence
	Hypermediality		Interoperability
	Support Tools	Portability	Adaptability
	Presentation		Installability
	User Interface		Replaceability
	Learning Contents	**ii. Quality in Use**	**Model Of ISO/IEC 25010**
	Accessibility Control	**Criteria**	**Sub-Criteria**
Portability	Adaptability	Satisfaction	Usefulness
	Installability		Trust
	Conformance		Pleasure
	Replaceability		Comfort
	DBMS Standards	Effectiveness	
	Middleware Standards	Freedom From Risk	Economic Risk Mitigation
	Standardability		Health and Safety Risk Mitigation
Efficiency	Time Behaviour		Enviromental Risk Mitigation
	Resource Behaviour	Efficiency	
	Memory Capacity	Context Coverage	Context Completeness
Cost	Licensing Cost		Flexibility
	Development Cost		
	Implementation Cost		
	Maintenance Cost		
	Upgrade Cost		
	Cost of Hardware		
	Training Cost		

'Table 5.23, Comparison Between ISQM and ISO/IEC 25010 Continued'

ISQM		ISO/IEC 25010	
		i. Product Quality Model Of ISO/IEC 25010	
Criteria	**Sub Criteria**	**Criteria**	**Sub-Criteria**
	Marginal Cost		
Vendor	Vendor Reputation		
	Vendor Support &Training		
	Vendor Services		
	User Manual/Documentation		
	Tutorial		
	Troubleshooting Guide		
	Training		
	Maintenance and Upgrading		
	Communication		
	Demo		
	Response Time		
	Length of Experience		
	Technical and Business Skills		
	Past Business Experience		
Organizational	Organizational Culture		
	Organizational Change		
	Organizational Politics		
	Organizational Resource		
	User Acceptance		
Product Benefit	User Satisfaction		
	Software Ease of Use		
	User Productivity		
	Cost Saving		
	After Sales Service		
Risk & Uncertainty	Vendor Risk		
	Product/Technological Risk		
	Software Bugs and Errors		
	Frequency of Software Release		
	Virus and SPAM		
	Unexpected Cost		
	Educational System Changed		

5.5 The Formulation of the ISQM-Fuzzy AHP Evaluation Framework for e-LS Evaluation

The evaluation and selection process of a software consist of several stages which include:

i. Plan the evaluation and the requirement definition;

ii. Preliminary investigation;

iii. Establishing of evaluation criteria;

iv. Shortlisting of software;

v. Selecting of software;

vi. Negotiating with vendor; and

vi. Purchasing of software.

These processes form a guideline that can be adapted according to the requirements of the individual organization for software selection (Jadhav & Sonar, 2011). However, the evaluation and selection software is considered a complex task because it consists of many processes.

As mentioned in Section 2.5.2, the evaluation of the software consists of several steps. For example, in the evaluation of the COTS, the following steps are normally taken:

i. Define the evaluation criteria based on stakeholders' requirements

ii. Search for COTS products;

iii. Filter the search results based on a set of requirements;

iv. Evaluate COTS alternatives on the short list; and

v. Analyse the evaluation data; and

vii. Select COTS products.

The ISQM framework, which is based on the COTS evaluation process, will be used in the e-LSO. The criteria and sub criteria of the ISQM are then stored in the e-LSO. The Fuzzy AHP technique is used for processing the rapid evaluation process.

5.5.1 The Relationship Between the ISQM, Fuzzy AHP Technique and the e-LSO

The proposed ISQM is incorporated together with the Fuzzy AHP technique in a software tool called the e-LSO. The tool was developed to support the evaluation process of the e-LS. The stages involved in the ISQM-Fuzzy AHP e-LS evaluation framework will be adapted from the steps noted in the COTS based evaluation process

(Ruhe, 20013). These steps, as noted in the COTS evaluation process, are consolidated in stages III, IV and V. The ISQM framework is then implemented in the e-LSO which is then used to evaluate the e-LS product. The steps involved in the ISQM-Fuzzy AHP framework is automated in the e-LSO modules. The Fuzzy AHP technique was used as an evaluation technique. The steps noted in the Fuzzy AHP technique were refined before being automated in the e-LSO modules. All information concerning the criteria and sub-criteria of the ISQM will be stored in the e-LSO database. Figure 5.6 shows the relationship between the ISQM, the Fuzzy AHP technique and the e-LSO. This will form the e-LS evaluation framework that can be used by organizations for evaluating the respective e-LS when implementing e-Learning.

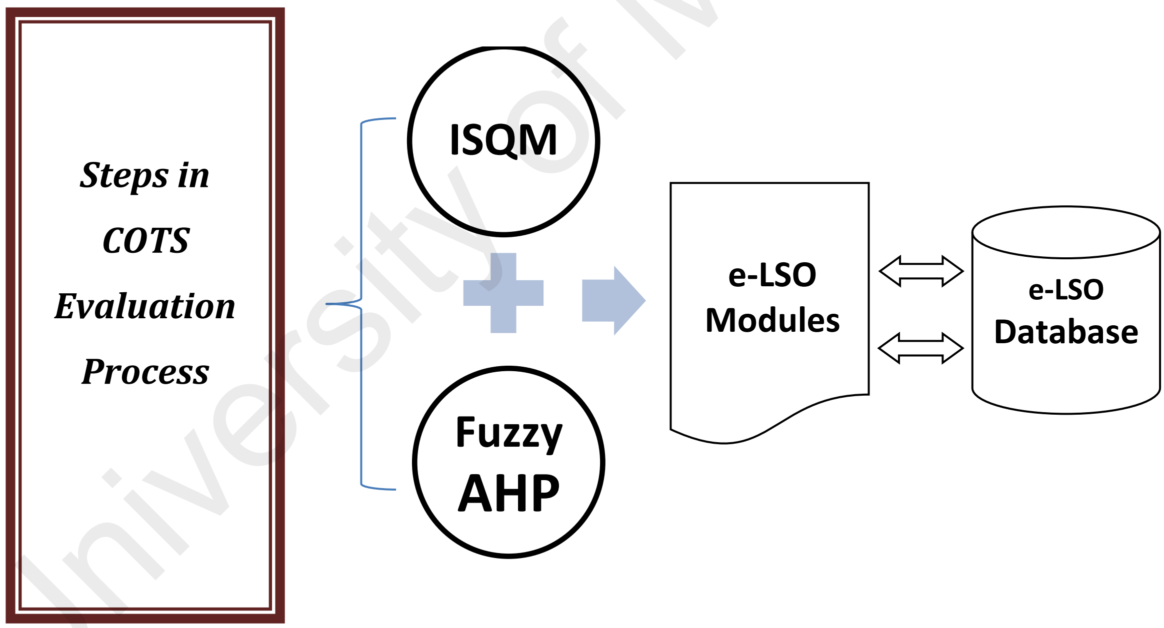


Figure 5.6: The Relationship Between the COTS Process, the ISQM, the Fuzzy AHP Technique and the e-LSO

5.5.2 Stages and Processes Involved in the ISQM-Fuzzy AHP Evaluation Framework

The proposed evaluation framework, hereby called the ISQM-Fuzzy AHP Framework that will be used for the e-LS evaluation will consist of six main stages.

The outline of the evaluation framework for the e-LS is shown in Figure 5.7 while the six stages involved are as follows:

a. Stage 1: Requirement identification process;
b. Stage II: User Management Process;
c. Stage III: Model Construction Process;
d. Stage IV: Evaluation Process;
e. Stage V: View Result Process; and
f. Stage VI: e-LS Selection Process

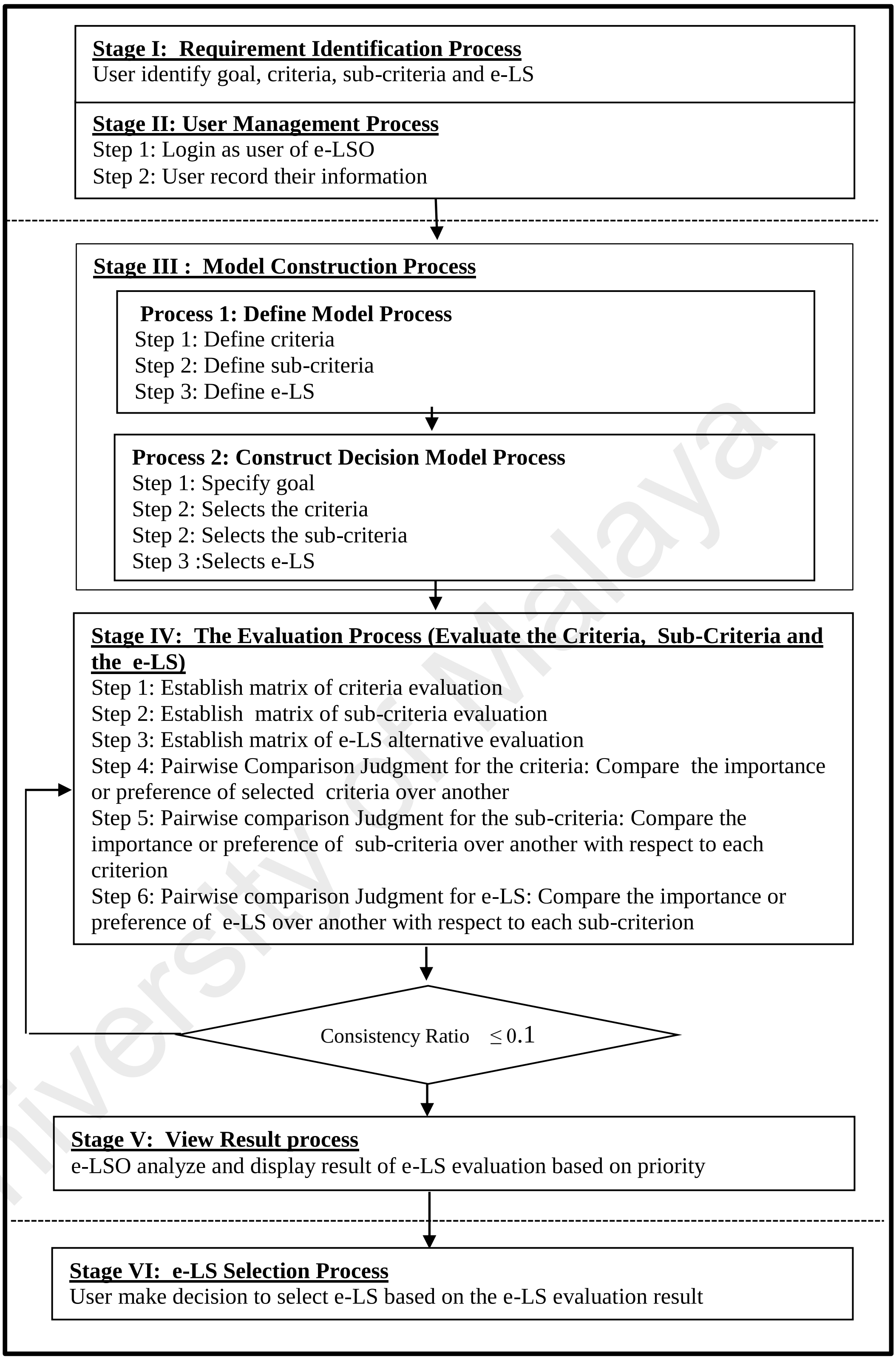


Figure 5.7: ISQM-Fuzzy AHP Evaluation Framework for e-LS Evaluation

5.5.2.1 Stage I: Requirement Identification Process

In Stage I, the users have to identify the requirement of the e-LS evaluation. They have to identify their goal of evaluation for the e-LS, the criteria and sub-criteria involved and the e-LS that is required in the evaluation process.

5.5.2.2 Stage II: User Management Process

In Stage II, the users have to login the e-LSO by using their authorized username and password. The login process enables the authorized user to access the e-LSO. The process would also include the registration of new users. This process will record information about the users of the e-LSO, for example, their company name, staff/name, staff id/number, position, email, login time and personal details. This process enables the e-LSO to recognize the user of the system of a particular session. The user of the e-LSO involves the decision makers, vendors, end users and administrators.

5.5.2.3 Stage III: Model Construction Process

Stage III consists of two processes:

1. Process 1: Define the Model Process

The e-LSO provides flexibility for the users to construct their own decision model based on their requirements. In this process, the users may filter the available criteria, sub-criteria and the e-LS provided in the e-LSO so as to define their own customized model. To accomplish this, the users only need to define their own criteria, sub-criteria and the selected e-LS.

2. Process 2: Construct Model Process

To construct the model, users are required to specify their goals. Following that, they select the criteria, sub-criteria and the e-LS from the e-LSO. Based on the Fuzzy AHP technique, the goal, criteria, sub-criteria and e-LS alternatives can then be decomposed into a hierarchical structure. This allows the Fuzzy AHP technique to obtain a decision model for the e-LS evaluation, as illustrated in Figure 5.8.

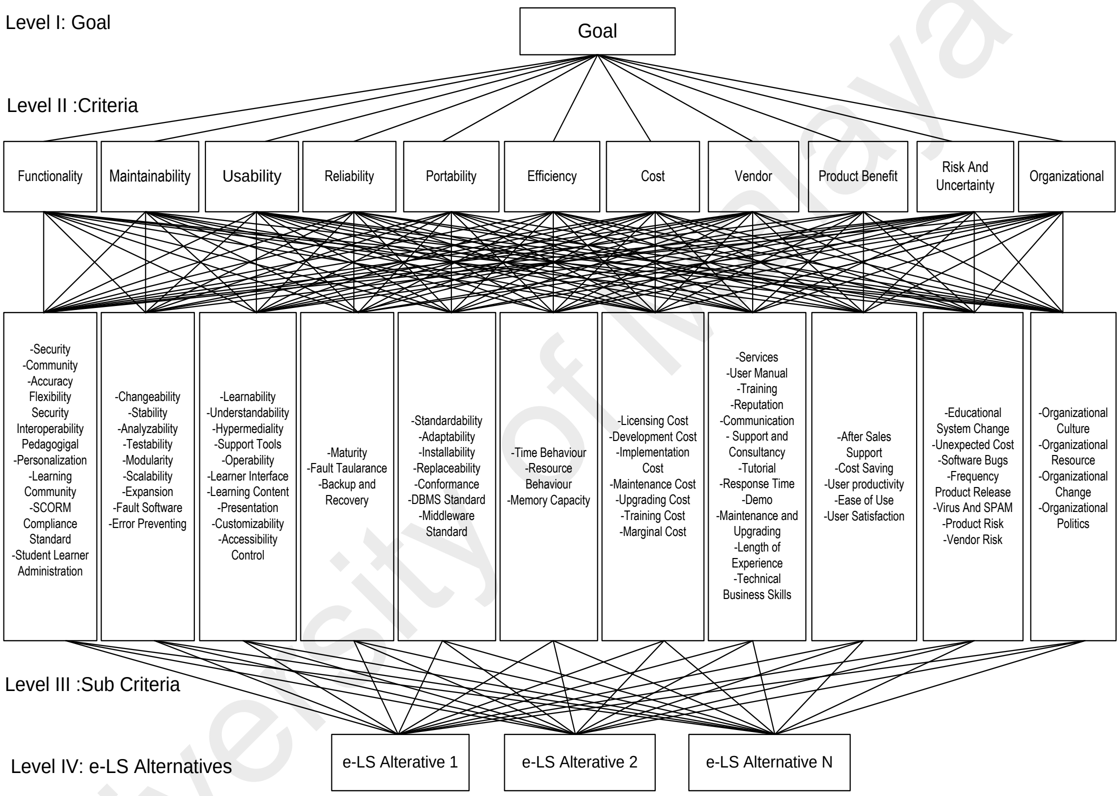


Figure 5.8: General Fuzzy AHP Based Decision Model for e-LS Evaluation

The decision model is made up of four 4 levels:

- Level 1: consists of a goal.
- Level II: consists of 11 evaluation criteria of the e-LS.
- Level III: consists of 81 evaluation sub-criteria of the e-LS.
- Level IV: consists of selected e-LS alternatives.

The hierarchical model of the e-LS evaluation can then be formed. The metrics for the criteria, sub-criteria and the e-LS alternatives can be established before the evaluation. The model definition process then defines the Fuzzy AHP based decision model.

With the assistance of the e-LSO, users are able to define their own decision model by selecting any evaluation criteria, sub-criteria and e-LS alternatives, based on their needs. In this regard, the e-LSO provides users with the flexibility to create their own decision model. The development of the Fuzzy AHP is discussed in detail in Chapter 7.

5.5.2.4 Stage IV: The Evaluation Process (Evaluate the Criteria, Sub-Criteria and the e-LS)

At Stage IV, the evaluation criteria, sub-criteria and the e-LS alternatives are evaluated by using a pairwise comparison. This is performed by comparing one criteria with another criteria. Following this, the Fuzzy weights will then use the linguistic scale to give weight to each particular pairwise comparison. The same process is also conducted for the sub-criteria pairwise comparison and the e-LS pairwise comparison.

5.5.2.5 Stage V: View Result Process

At Stage V, the process allows the model and the evaluation results to be viewed. The data analysis supports the evaluation of each alternative as the evaluation results are viewed. All the processes will be represented in the e-LSO.

5.5.2.6 Stage VI: e-LS Selection Process

At Stage VI, the experts make their decision with regards to the selection of the e-LS. This is based on the results acquired from the previous evaluation session.

As described above, the ISQM-Fuzzy AHP evaluation framework that was developed comprises a sequence of processes. This is to ensure that the users follow an appropriate process so as to acquire a more accurate evaluation. Moreover, the ISQM-Fuzzy AHP evaluation framework that was developed will also be supported by the Fuzzy AHP technique which provides mathematical assistance for the evaluation framework. Here, the Fuzzy AHP technique not only creates the pairwise comparison judgments for the evaluation criteria or sub-criteria being evaluated, it will also provide the mathematical calculation formula which analyses the pairwise comparison judgments. Through the differences seen in the calculations, users can then determine for themselves what decisions to make. In this regard, the e-LSO that was developed can help to improve the effectiveness of the e-LS evaluation process for the users.

The sequence of processes noted in the ISQM-Fuzzy AHP evaluation framework mentioned above will ensure that the e-LSO guideline is used adequately and according to the respective stages, in particular, Stages II, III, IV and V. By using this evaluation framework as a guideline, organizations are not only able to make better and more accurate decisions for the e-LS alternatives, they will also be able to use the e-LSO to construct their own decision model for the evaluation and selection of the e-LS intended, according to their respective organizational needs. Table 5.24 shows a comparison of the general evaluation process, the COTS evaluation process and the ISQM-Fuzzy AHP evaluation framework processes.

Table 5.24: Comparison of the General Software Evaluation Process, the COTS Evaluation Process and the ISQM-Fuzzy AHP Evaluation Framework Process

Software Evaluation Process	**COTS Evaluation Process**	**The ISQM-Fuzzy AHP Evaluation Framework Processes**
i. Plan the evaluation and requirement definition ii. Preliminary Investigation iii. Establish Evaluation Criteria iv. Short listing of Software v. Evaluating of Software vi. Selecting of Software vii. Negotiating with vendor viii. Purchasing of software	i. Define the evaluation criteria based on requirements ii. Search for COTS products iii. Filter the search result based on requirement iv. Evaluate COTS alternatives on the shortlist v. Analyze the evaluation data	i. Requirement identification Process ii. User Management Process - Log In - User Information iii. Model Construction Process - Define Model Process - Define Criteria - Define Sub-Criteria - Define e-LS - Construct Decision Model Process iv. Evaluation Process Step 1: Establish matrix of criteria evaluation Step 2: Establish matrix of sub-criteria evaluation Step 3: Establish matrix of e-LS alternative evaluation Step 4: Pairwise Comparison Judgment for the criteria : Compare the importance or preference of selected criteria over another Step 5: Pairwise comparison Judgment for the sub- criteria : Compare the importance or preference of sub-criteria over another with respect to each criterion Step 6: Pairwise comparison Judgment for e-LS: Compare the importance or preference of e-LS over another with respect to each sub-criterion v. View Result Process - Analyze the evaluation data and display result vi. e-LS Selection Process - User make decision to select e-LS based on the e-LS evaluation result

5.6 Summary

This chapter has described the formulation of the ISQM-Fuzzy AHP evaluation framework which can be applied for the evaluation of the e-LS by organizations. The first step of the formulation, involved doing a thorough literature review of the related articles in order to identify the relevant evaluation criteria and sub-criteria that can be used for the formulation of the framework. This was followed by a two-round Delphi survey of 31 experts. The aim was to identify any additional criteria and sub-criteria from the experts, besides getting them to validate the final list of the criteria and sub-criteria proposed. To do this, the IQR, the Median values as well as the priority ranking results were analyzed. A total of 11 evaluation criteria were validated by the experts as important for the e-LS evaluation. This validation from the experts also included six additional criteria that had been extracted from the ISO-9126 Quality Model and five additional criteria that had been taken from the COTS framework. From the total of 82 sub-criteria that were validated by the experts to be Important, it was noted that 66 were those detected from literature while the remaining 16 were the additional sub-criteria that had been proposed and validated by the experts. Overall, one sub-criterion was rejected due to a low consensus from the experts or did not achieve the majority of experts consensus during the Delphi survey. The final 11 criteria and 81 sub-criteria were then incorporated into the ISQM model. Finally, a framework was constructed to integrate the ISQM together with the Fuzzy AHP technique in the form of a systematic sequence of process which can be used by users for the e-LS evaluation. The development of the tool is discussed in detail in Chapter 6.

CHAPTER 6: e-LSO TOOL DEVELOPMENT

6.1 Introduction

The preliminary study reported in Chapter 4 had shown that there was a need to have a support tool that can assist organizations in the evaluation and selection process of the e-LS. To the best of the researcher's knowledge and also based on current literature review, no such tool is presently available, particularly for the use of Malaysian organizations that are implementing e-Learning. This chapter discusses the development of such a tool based on the ISQM-Fuzzy AHP evaluation framework that was developed in Chapter 5.

6.2 e-LSO Development

Section 5.5 has identified several processes which were adapted into the proposed e-LS evaluation framework. This framework was suggested and then used to develop a support tool called the e-LSO. This tool can be used by organizations in Malaysia when evaluating the e-LS during the implementation of e-Learning within their organizations. The main criteria and sub-criteria identified as well as the e-LS alternatives which have been distinguished for the evaluation process can be stored in the e-LSO which, simultaneously, also uses the Fuzzy AHP technique. As a support tool, the e-LSO, when used, would allow organizations to easily create their own models for evaluating and selecting the e-LS products. In addition, the organizations can also use the e-LSO as alternatives in assisting them in the evaluation and selection process of the e-LS, based on their needs.

6.3 e-LSO Architecture

The proposed e-LSO was developed through a web based environment. It was designed in 3-tier architecture. The proposed 3-tier architecture allows the user to access the e-LSO tool via the internet medium. The e-LSO was proposed as a supporting tool for the evaluation and selection process of the e-LS by organizations implementing e-Learning. The main aim of the e-LSO is to assist users in making the appropriate decisions when using web applications. The users of the e-LSO would be the decision makers, end-users and administrators. These users can interact with the e-LSO via the e-LSO interface. The evaluation sessions are then recorded and kept in the database. Figure 6.1 shows the architecture of the e-LSO.

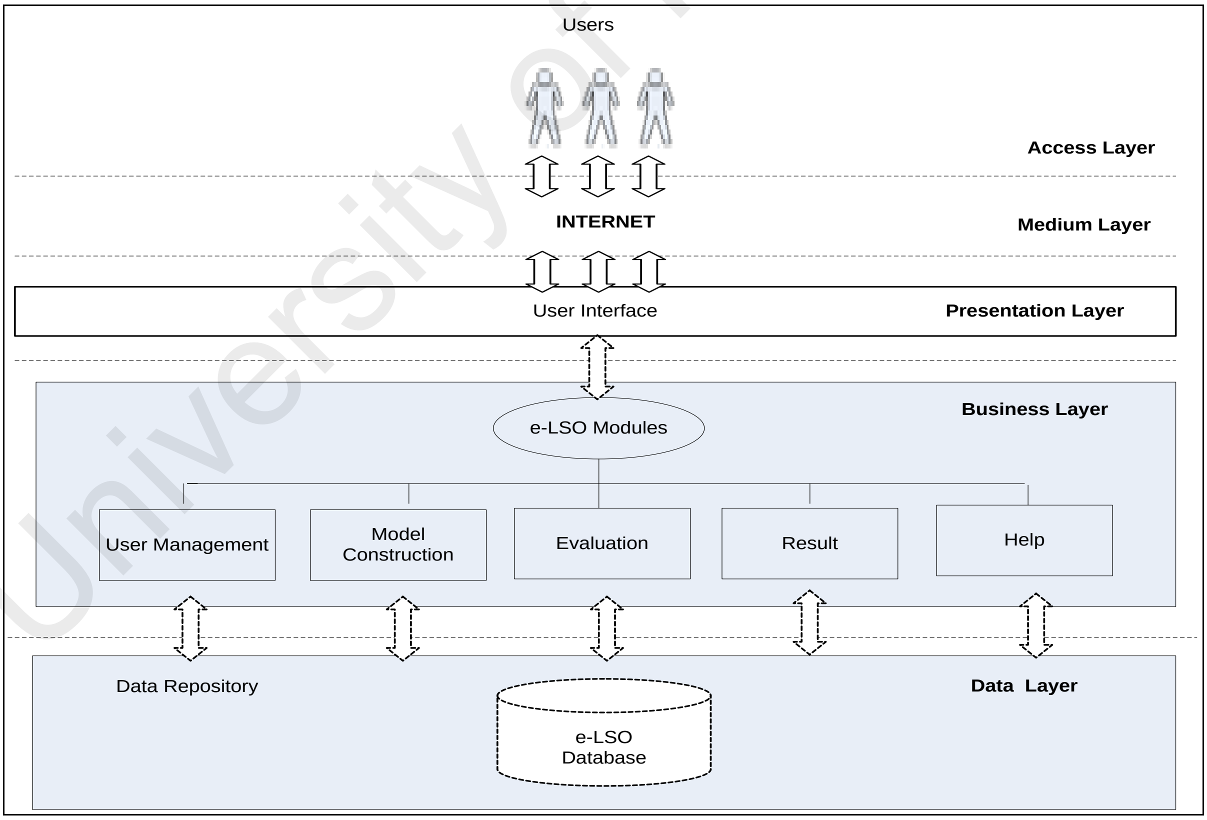


Figure 6.1: e-LSO Architecture

6.3.1 e-LSO Modules

When using the e-LSO, users are required to log into the e-LSO interface through an authorized username or id and a valid and authorized password before they are granted access to the available system modules. The e-LSO comprises five modules which include: i) User management Module; ii) Model Construction Module; iii) Evaluation Module; iv) Result Module; and v) Help Module. Figure 6.2 illustrates Modules and Sub-Modules of e-LSO.

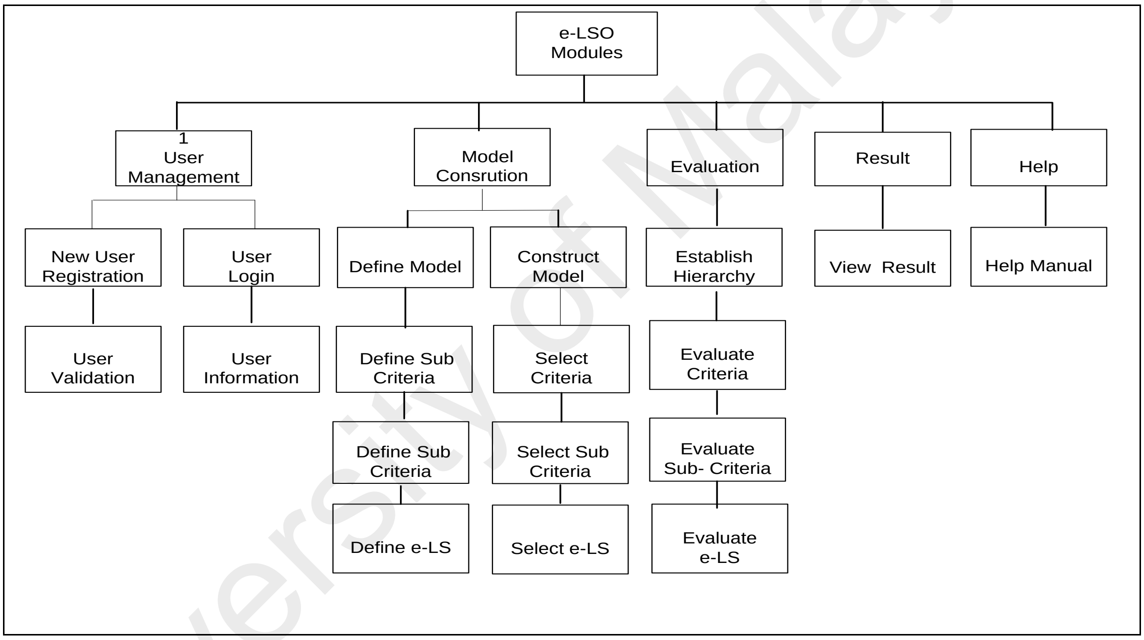


Figure 6.2: Modules and Sub-Modules of e-LSO

6.3.1.1 User Management Module

The User Management module organizes the information regarding the users in the e-LSO. This module also consists of two sub-modules:

a. New User Registration

The first sub module comprises the New User Registration where users' information including names, addresses, post codes, phone numbers, names of organizations, email addresses and nature of the applications, are obtained. The second sub-module is User Information where the module would recognize a certain session of the evaluation and selection process made by a certain applicant. This sub-module also allows the users to add/delete or update the relevant information that is required by the e-LSO.

b. User Log in

As a second module of the e-LSO, the User Log in module manages the log in processes made by users when making efforts to use the e-LSO. Users can only log into the system by using the authorized username and password provided in the first module. Once this is approved and the log in system is successful, the users are given access to the other modules.

6.3.1.2 Model Construction Module

The third module or the Model Construction Module enables users to define and construct the model.

a. Define Model

As stated above, users define and construct the decision model for the e-LS evaluation. The criteria, sub-criteria and the e-LS alternatives have already been stored in the e-LSO by the administration, the users can then proceed with the process. In the preliminary survey, eight e-LS alternatives were obtained and these would serve as the default in the e-LSO as it enables the users to make their selections for their e-LS evaluation. However, since the e-LSO was developed as a support tool that also provides flexibility to the users in terms of defining their own criteria, sub-criteria and e-LS alternatives, instead of just those provided by the e-LSO, the users will thus need to create their own e-LS alternatives, where necessary.

b. Construct Model

Once the users have defined their model through the e-LSO, they can proceed to constructing their own model for the evaluation process. At this stage, users are required to develop and create their own goals; they also need to select the criteria and sub-criteria necessary for evaluating their e-LS, from their own database. Nonetheless, users may also select their own e-LS based on the selection of several e-LS alternatives made available in the e-LSO.

6.3.1.3 Evaluation Module

Once the other modules have been accessed, the evaluation module would allow the users to evaluate the criteria, sub-criteria, and the e-LS. The hierarchy model of the e-LSO can be viewed through this module. While at this phase of the module, users can compare and assign weights for each criterion, sub-criterion and the e-LS in pairwise comparisons. The evaluation metric can also be viewed and this would allow the users to evaluate and provide weights to the criteria, sub-criteria and e-LS thereby, making comparisons. The consistency ratio values can then be calculated in the e-LSO as a measure to validate the pairwise comparison judgments in order to see if they are consistent. The consistency ratio simply reflects the consistency of the pairwise judgments. The users can also test the validity of the weights that were derived from the pairwise comparison analysis thereby ensuring that the e-LSO is also able to calculate the weight values of each criterion, sub-criterion and the e-LS comparison.

6.3.1.4 View Result Module

This module allows the users to display their results. The e-LSO would be able to analyze the results automatically. The calculations of the pairwise comparison for the criteria, sub criteria and alternatives would be automatically done by the e-LSO through the Fuzzy AHP technique. The viewed module would then highlight the weight of the pairwise comparison judgment with respect to the evaluation criteria, sub-criteria and e-LS alternatives. The results and the hierarchy of the criteria can be displayed either in the horizontal or vertical view orientation.

6.3.1.5 Help Module

The Help Module consists of a user manual and it aims to assist users in using the e-LSO more efficiently.

6.3.2 Summary Module and Sub-Module of e-LSO

Table 6.1 shows the summary of the e-LSO modules and their functions.

Table 6.1: A summary of the Modules and Sub-Modules of the e-LSO

Module and Sub Module	Users	Function
a. User Management Module		
i. Login		
Sign Up	Authorized Users	Enable user to add Information
Sign in	Authorized Users	Enable user to sign up to e-LSO
ii. New User Registration		
User Validation	Admin/Authorized Users	Enable user to add new Criteria
i. User Information		
User Information Registration	Admin/Authorized Users	Enable user to add new Criteria
Logout	All users	Enable user to logout from e-LSO
b. Model Construction Module		
i. Define Model	Admin/Authorized Users	Enable user to add new Criteria
Define Criteria	Admin/Authorized users	Enable user to add Sub-Criteria
Define Sub-Criteria	Admin/Authorized users	Enable user to add Sub-Criteria
Define e-LS alternatives	Admin/ Vendor	Enable user to add e-LS
ii. Construct Model		
Create Goal	Authorized Users	Enable user to add/update Goal
Select Criteria	Authorized Users	Enable user to select Criteria
Select Sub-Criteria	Authorized Users	Enable user to select Sub-Criteria
Select e-LS	Authorized Users	Enable user to select e-LS
iii. Other Facility	Admin/Authorized users	
Search/Filter Criteria	Admin/Authorized users	Enable user to search and filter Criteria
Search/Filter Sub-Criteria	Admin/Authorized users	Enable user to search and filter Sub-Criteria
Search/Filter e-LS	Admin/Authorized users	Enable user to search and filter e-LS
c. Evaluation Module		
i. Establish Hierarchy Model	Authorized Users	Enable user to view hierarchy model and evaluation Metric
ii. Evaluate Criteria - Compare and Weight Criteria	Authorized Users	Enable user to compare evaluation criteria and provide weight
iii. Evaluate Sub-Criteria - Compare and Weight Sub-Criteria	Authorized Users	Enable user to compare evaluation sub-criteria and provide weight
iv. Evaluate e-LS - Compare and Weight e-LS	Authorized Users	Enable user to compare e-LS and provide weight
vi .View Consistency	Authorized Users	Enable user to view consistency from pair wise comparison
d. View Result Module	Authorized Users	Enable user to view result
e. Help Module	All Users	View guideline of using e-LSO tool

6.4 e-LSO Design

The design of the e-LSO is presented in this section.

6.4.1 Context Diagram

The Context Diagram (CD) provides the connection between the external users and the e-LSO. The users for this system, as stated earlier, are authorized users and their levels may vary from decision makers, end users to the administrators. A Context Diagram is the highest level of the Data Flow Diagram which shows the system boundaries and the external entities that are interacting with the system. It also shows the major information flow between the entities and the system (Nielson, 2000). The e-LSO, upon being used, would also receive instructions from users. It would also be able to process the information provided by the users and these would then be stored in the DBMS for future use. Figure 6.3 illustrates the Context Diagram of the e-LSO.

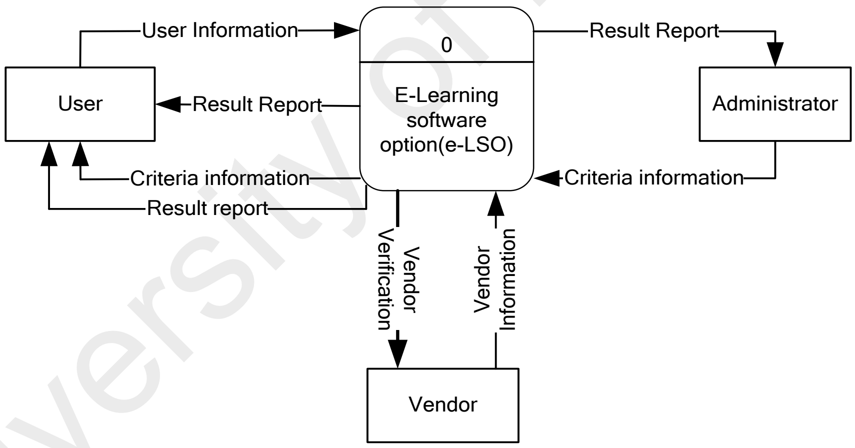


Figure 6.3: Context Diagram of e-LSO

6.4.2 Data Flow Diagram of e-LSO

The Data Flow Diagram (DFD) illustrates the movement of data which occur between the external entities and the process as well as the data that are stored within the system (Nielson, 2000). The DFD depicts the flow of the data through a system and the work or process performed by the system (Omar et al., 2011). The data and information are stored in several tables. The overall DFD level 0 is shown in Figure 6.4.

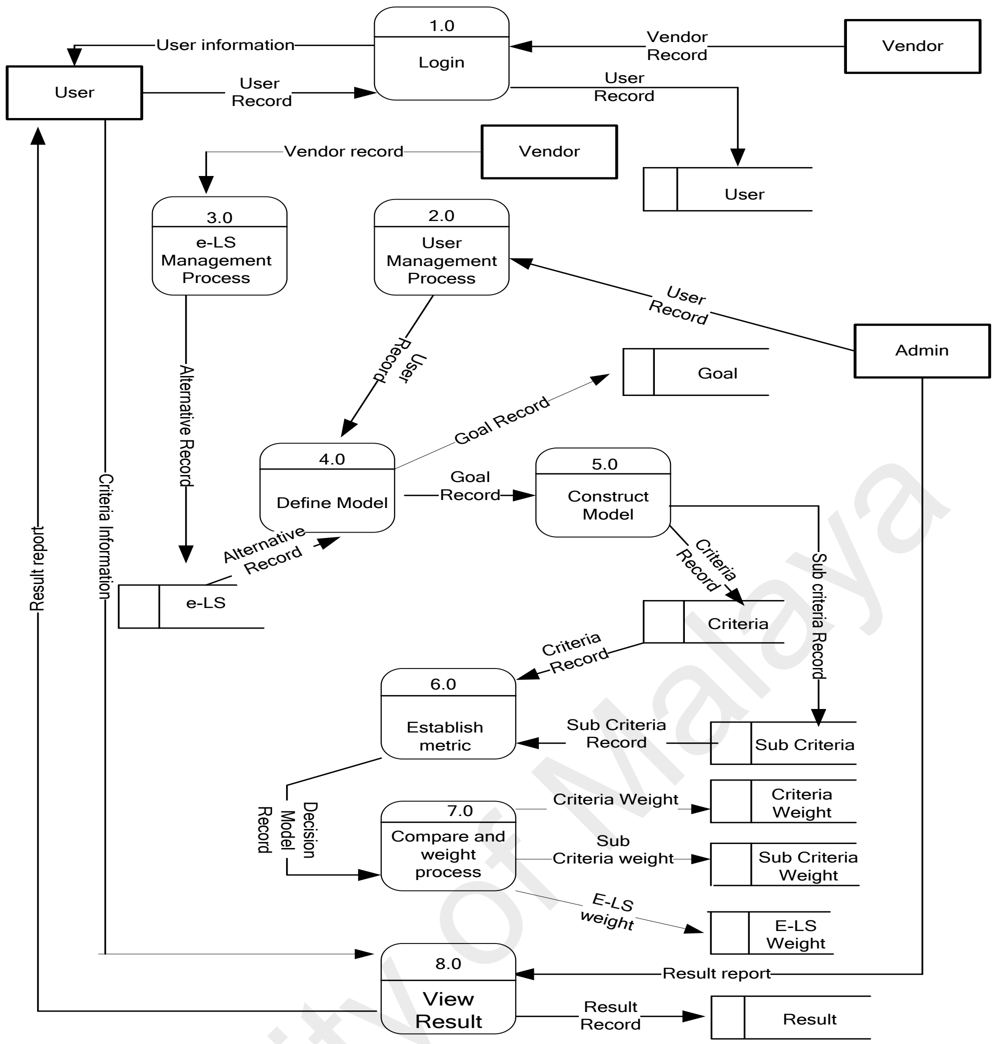


Figure 6.4: Data Flow Diagram of e-LSO

6.4.3 Entity Relationship Diagram

From the DFD, the Entity Relationship Diagram (ERD) can be designed. This is shown in Figure 6.5.

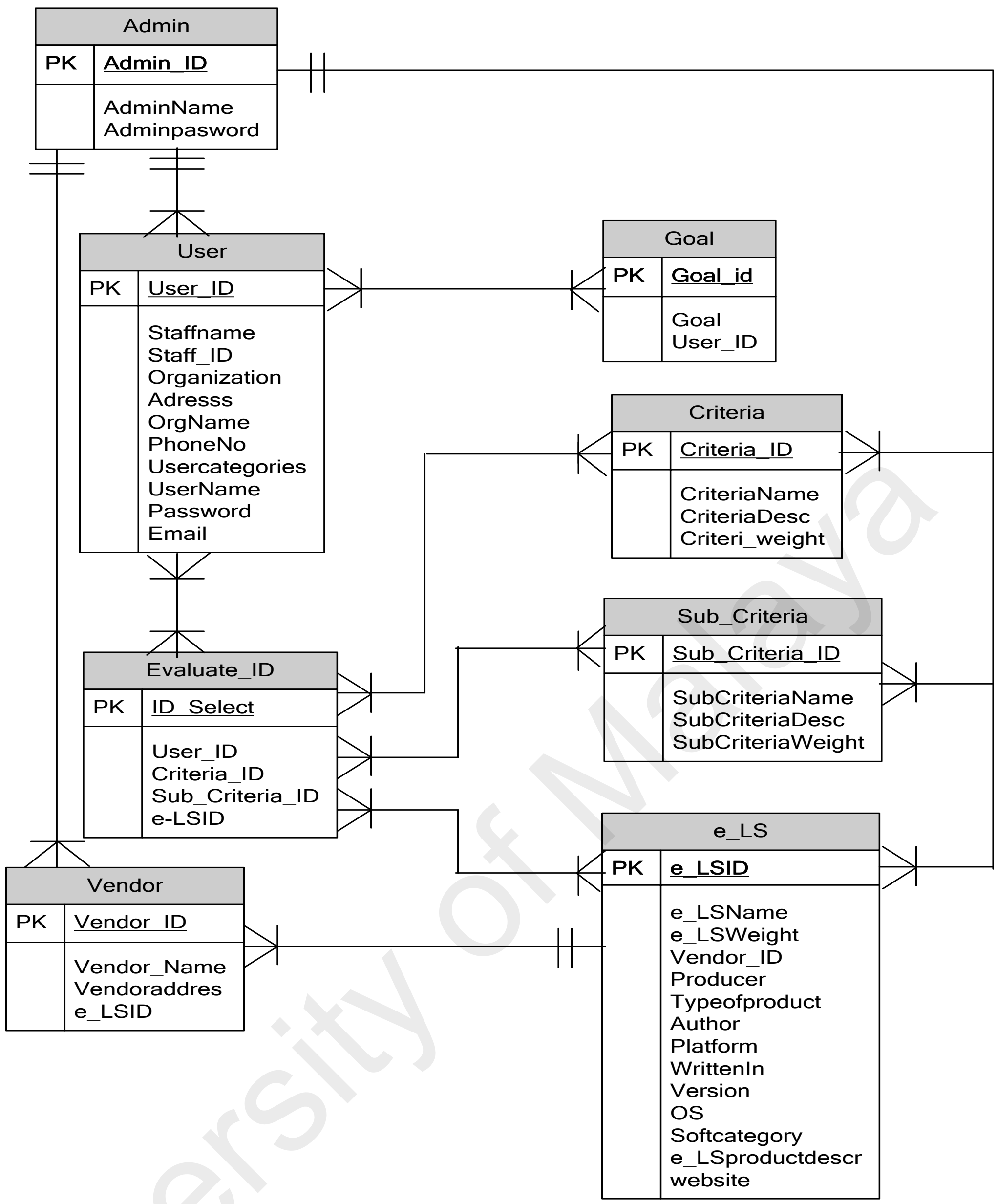


Figure 6.5: Entity Relationship Diagram of e-LSO

6.4.4 Database Design

The ERD, as described in Section 6.4.3, is then used to design the e-LSO database which uses the MySQL.

6.5 e-LSO Interface

The main interface of the e-LSO allows users to access important information stored within the system functions. These users may also communicate with the e-LSO through an authorized user id and password, as mentioned above. The menu interface provided by the e-LSO can only be accessed by authorized users and it consists of items such as session management, construct model, evaluation, result and analysis and help menu. Figure 6.6 displays the e-LSO interface in use.

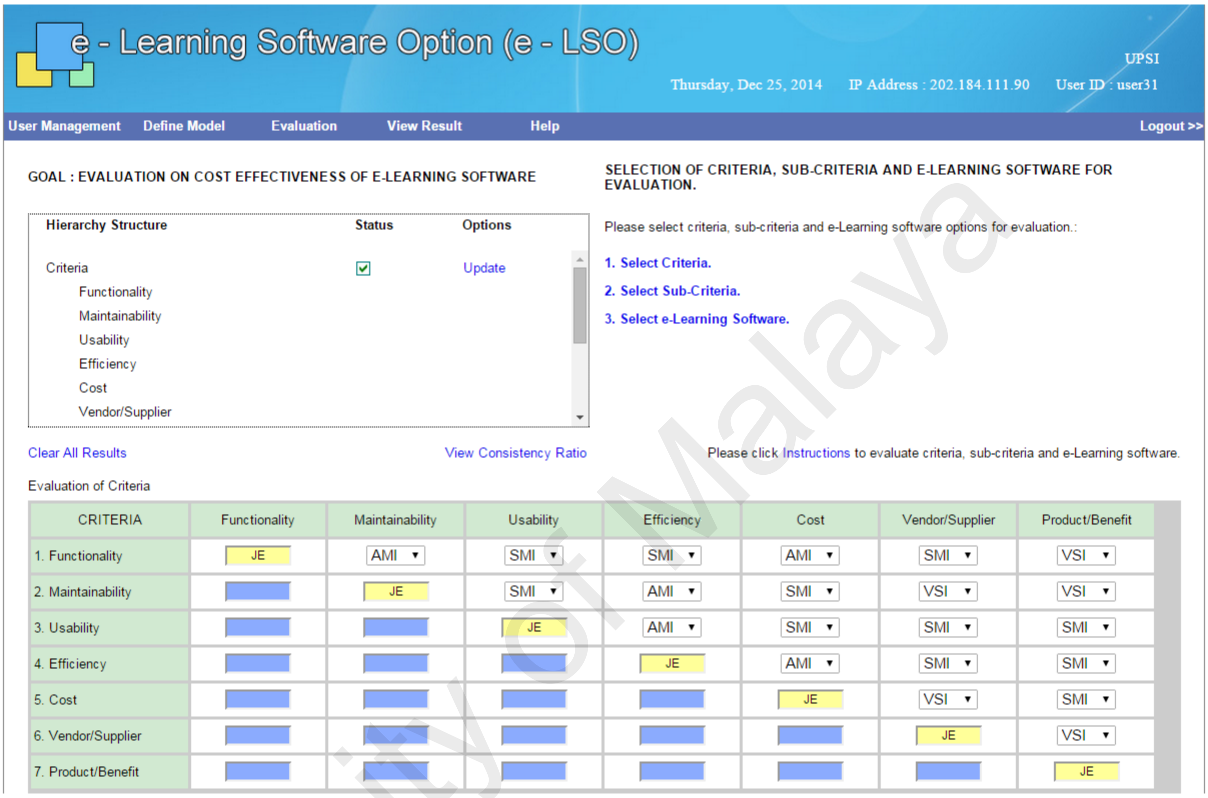


Figure 6.6: Sample of e-LSO Interface

The e-LSO module and its related interfaces are explained in detail in Appendix J.

6.6 Evaluation Process, Technique and Criteria in Software Evaluation Tool

In this section, the e-LSO and other existing software tools are compared. Most software evaluation approaches consist of several processes and procedural steps. However, these processes may differ from another as some of the processes in one approach may be omitted by another approach. For example, the DesCOTS tool takes into consideration the quality criteria of COTS software. However, it omits important consideration for *Costs*, *Vendors* and *Product Benefits*. The EW-LMS tool, in comparison, only focuses on the features of LMS as an evaluation criteria and nothing else. The developed e-LSO, nevertheless, offers users a wider flexibility to create their own evaluation models based on the needs of their organizations. The Fuzzy AHP technique used in the developed e-LS also provides users with a sequence of processes which can assist these users in the evaluation of the criteria, sub-criteria and the e-LS through the pairwise comparison judgment. Moreover, the e-LSO also allows users to select from their own list of validated criteria and sub-criteria and e-LS alternatives in order to create their own evaluation model. Further to that, the developed e-LSO offers users the flexibility in expanding the list of e-LS alternatives available, thereby, giving users more options in their selection process.

Overall, it can be said that the developed e-LSO which was created in a web-based environment enables consolidation with other processes such as authorised login and user management processes. This makes the e-LSO a current, modern and practical online tool for use. The other advantage of the e-LSO is that it offers users, irrespective of whether they are administrators or vendors, the option of providing new information which can be easily fed into the e-LS for evaluation purposes instead of using those already stored in the e-LSO database.

A comparison of the Evaluation Process, Technique and Criteria used in the Software Evaluation Tool is shown in Table 6.2.

A comparison of the Evaluation Process, Technique and Criteria in the Software Evaluation Tool is shown in Table 6.2.

Table 6.2: Evaluation Process, Evaluation Technique and Evaluation Criteria in Software Evaluation Tool

1. Processes in the evaluation of Software	**DesCOTS**	**EW-LMS**	**Fuzzy AHP Tool (Mehregan, et al. 2011)**	**e-LSO**
Define the evaluation criteria	X	-	X	X
Search or Filter and Select Criteria	X	X	-	X
Search or Filter and Select Sub-Criteria	-	-	-	X
Search or Filter and Select Software	X	X	-	X
Evaluate Criteria	-	-	X	X
Evaluate Sub-Criteria	-	-	-	X
Evaluate software	-	X	X	X
Filter / View result	-	X	X	X
Select Software	X	X	X	X
2. Other Processes	**DesCOTS**	-	-	**e-LSO**
Login Process	-	-	-	X
User Management process	-	-	-	X
Goal definition		-	-	X
Hierarchical Model Construction	**X**	-	-	X
Display Pairwise Evaluation Matrix	**X**	-	X	
e-LS management	-	-	-	X
3. Evaluation technique	-	-	-	**e-LSO**
Evaluation technique used	-	-	Fuzzy AHP	Fuzzy AHP
4. Evaluation criteria	-	-	-	
Functionality	-	-	-	X
Efficiency	-	-	-	X
Maintainability	X	-	-	X
Reliability	X	-	-	X
Usability	X	-	-	X
Portability	X	-	-	X
Reusability	-	-	-	X
Cost	-	-	-	X
Vendor	-	-	-	X
Product Benefit	-	-	-	X
Risk & Uncertainty	-	-	-	X
5. Other Criteria and Sub-criteria	-	Features of LMS	-	Flexible to add other criteria and sub-criteria

6.7 Summary

This chapter has discussed the development of the e-LSO which was aimed at assisting organizations in the evaluation process of the e-LS used during the implementation of e-Learning. The architecture of the e-LSO and its related modules have been described. This encompasses the design of the Context Diagram, the Data Flow Diagram and the ERD of the system. The web-based user interface was also illustrated, showing the various consolidated modules and the layout of the user interface. A comparison was also made on the features of the developed e-LSO with other tools, thereby, highlighting the comprehensiveness of the developed e-LSO.

CHAPTER 7: e-LSO EVALUATION

7.1 Introduction

This chapter presents the usability evaluation results of the e-LSO. In the previous chapter, it was revealed that the e-LSO was developed as a support tool based on the ISQM-Fuzzy AHP framework. By evaluating the usability of the e-LSO, the ISQM-Fuzzy AHP framework can also be verified simultaneously. The procedure for the usability evaluation has been discussed in Section 3.5.3. Five experts comprising e-Learning practitioners with knowledge in e-Learning and the e-LS and have worked among organizations in Malaysia, were invited to participate in the usability evaluation of the e-LSO. As mentioned in Section 3.5.2, the 5 experts were new respondents who had not participated in the preliminary survey nor the Delphi survey phases of this study.

All the five experts had more than 15 years of experience in Information Technology including the e-Learning domain. They were also those who were directly involved in the evaluation and selection process of the e-LS for e-Learning implementation in their organizations. Expert 1 (E1) is the Chief Information Officer who led the implementation of the e-Learning project in his organization. He was also directly involved in the evaluation and selection of the e-LS. Expert 2 (E2) is a Senior IT Officer who was responsible for managing the e-Learning project in his organization. He also worked with members of the e-Learning development team that implements e-Learning in his organization. He was invited by the top management of his organization to participate in the evaluation process when selecting the e-LS for his organization. Expert 3 (E3) is an IT manager who was given the responsibility to manage the e-Learning department in his organization. He was involved in the e-Learning project from the beginning of the project until its implementation in his organization. Expert 4 (E4) is an academician who was also appointed as the e-Learning Director. He was responsible for the planning and implementation of the e-Learning issue in his University. Expert 5 (E5) was the e-Learning Coordinator who was appointed by the university to participate as a committee in the evaluation and selection process of the e-LS. She was also responsible for ensuring the successful implementation of e-Learning in her University.

This chapter reports on the usability evaluation results as given by the five experts. The reports are divided into several sections. The results of the experts' current practices on the e-LS evaluation are presented first. This is followed by a report about the application of the ISQM framework and the construction of the Fuzzy AHP model as seen in the e-LSO which is used to evaluate the e-LS. The results of the usability evaluation of the e-LSO are presented last.

7.2 Experts' Current Practice on e-LS Evaluation

The questionnaire administered to the five experts aim to draw on their current practices applied in their e-LS evaluation. The questionnaire aims to collect information about their e-Learning implementation, the stages involved in the evaluation and selection of the e-LS, the establishment of the e-LS criteria, how the e-LS criteria were considered in evaluating the e-LS, the evaluation techniques used, the support tools applied and other problems noted in the e-LS evaluation. A sample of the questionnaire is included in Appendix G.

a. e-Learning Implementation

The first part of the questionnaire asked the experts to indicate the type of e-LS that they have evaluated or developed. Four experts E1, E3, E4 and E5 have used Moodle which is an open-source LMS. E1 has also used the PHP with Moodle to construct e-learning applications for the organization. However, E2 has used the Microsoft.net and the commercial software to construct e-learning applications. This was due to the need for developing the e-learning applications from scratch.

b. Stages in the Evaluation and Selection of the e-LS

The experts were then asked to select the various stages which were performed in the evaluation of the e-LS. It appears that the most commonly used stages as depicted by the experts were those of the requirement definition, preliminary investigation, shortlisting software products, establishing criteria for evaluation, evaluating of software packages, selecting software packages, negotiating with vendor and purchasing and implementing the most appropriate software. It also appears that the stages selected by the experts differ from one expert to another. While E1, E2, E3 and E5 went through five stages in the evaluation of the e-LS, one, E4 performed all the stages noted. Figure 7.1 shows the results of the stages taken by the experts.

	S: Stages	E1	E2	E3	E4	E5
S8(5)	Purchasing and implementing the most appropriate software package	X	X	X	X	X
S7(1)	Negotiating with vendor	-	-	-	X	-
S6(5)	Selecting of software packages	X	X	X	X	X
S5(5)	Evaluating of software packages	X	X	X	X	X
S4(3)	Establishing of criteria for evaluation	X	-	X	X	-
S3(3)	Short listing of software products	-	X	-	X	X
S2(2)	Preliminary investigation	-	X	-	X	X
S1(3)	Requirement definition	X	-	X	X	-

E: Experts

Figure 7.1: Stages in the Process of Evaluating e-LS

c. Determine and Establish the Evaluation Criteria

Information on how the experts determined and established the evaluation criteria were also collected. The top three methods used were Internet surfing, vendor suggestion and referring to the ISO/IEC 9216-1 Quality Model. E4 mentioned that he utilized four different methods while E1, E2, and E3 used three methods and E5 used only two. Figure 7.2 presents the methods used by the experts to determine the evaluation criteria.

	DEEC: Determine and Establish Evaluation Criteria	E1	E2	E3	E4	E5
DEEC6(3)	Web site/Internet surfing	-	X	-	X	X
DEEC5(2)	Contact interview with users	X	-	X	-	-
DEEC4(2)	Conduct internal meeting and brainstorming	-	X	-	X	-
DEEC3(2)	Pamphlet/catalogue/article/ Product documentation	-	X	-	-	X
DEEC2(3)	Provided or suggested by vendor	X	-	X	X	-
DEEC1(3)	Refers to ISO/IEC9126-1 Quality Model	X	-	X	X	-

E: Experts

Figure 7.2: Determine and Establish the Evaluation Criteria of e-LS

d. Evaluation Criteria that Were Considered in Evaluating the e-LS

The survey indicated that ten out of the eleven criteria were considered by all the experts in the evaluation process. *Functionality* and *Usability* were the most used criteria. The criteria such as *Product Benefit* and *Risk and Uncertainty were* only considered once by different experts. *Maintainability, Efficiency* and *Cost* were used by three experts while two experts chose *Reliability* and *Vendor* as the evaluation criteria. From these, it can be seen that the number of criteria used in the e-LS evaluation varied between experts. For example, E2 and E4 evaluated the e-LS based on seven criteria while E3 only considered three criteria. Figure 7.3 shows the criteria that the experts considered when they evaluated the e-LS in the evaluation phase.

C: Criteria		E1	E2	E3	E4	E5
C11(0)	*Organizational*	-	-	-	-	-
C10(1)	*Risk & Uncertainty*	X	-	-	-	-
C9(1)	*Product Benefit*	-	-	-	X	-
C8(2)	*Vendor*	-	X	-	X	-
C7(3)	*Cost*	-	X	X	X	-
C6(3)	*Efficiency*	X	X	-	X	-
C5(2)	*Portability*	X	X	-	-	-
C4(2)	*Reliability*	-	X	-	-	X
C3(5)	*Usability*	X	X	X	X	X
C2(3)	*Maintainability*	X	-	-	X	X
C1(5)	*Functionality*	X	X	X	X	X

E: Experts

Figure 7.3: Criteria that Experts Considered in the Evaluation Phase

e. Evaluation Methods and Techniques

In looking at the method and evaluation techniques used by the experts in their e-LS evaluation, it was found that the experts preferred to review documentation and conduct internal meetings to evaluate the e-LS. The Scoring method was also used but only by three experts, namely E1, E3 and E4 while E5 used the benchmark technique to evaluate the e-LS. The other methods/techniques were not employed by these experts. The result displaying the evaluation methods/techniques used by the experts is shown in Figure 7.4.

MT: Method and Technique		E1	E2	E3	E4	E5
MT8(0)	Fuzzy AHP	-	-	-	-	-
MT7(0)	AHP	-	-	-	-	-
MT6(0)	Weight Method	-	-	-	-	-
MT5(0)	Rank technique	-	-	-	-	-
MT4(0)	Benchmark report	-	-	-	-	X
MT3(3)	Scoring Method	X	-	X	X	-
MT2(5)	Review documentation, pamphlet and article from software providers	X	X	X	X	X
MT1(5)	Conduct Internal Meeting	X	X	X	X	X

E: experts

Figure 7.4: The Method and Technique Used by Experts

f. Support Tools Used

With regards to the questions posed about the support tools, none of the five experts had used any support tools when evaluating the e-LS. They, however, felt that a support tool could assist in the evaluation and selection process of the e-LS. One expert also believed that a support tool could assist organizations into making a fast and correct decision when evaluating the e-LS.

g. Problems Encountered in the Evaluation and Selection of the e-LS

All the experts reported that they faced at least one problem that is related to the evaluation criteria (PE1, PE2, and PE3). The main problem experienced by most of the experts was the lack of information on e-LS selection criteria, followed by the subjective nature of the evaluation criteria, vendor reliance and the lack of support tools. Two of the experts indicated a lack of guideline; they also commented that the longwinded selection process was their main concern. None of the experts had any problem in applying their current evaluation technique. E3 and E4 had encountered the most number of problems as compared to the others. The problems that the experts encountered in the evaluation and selection of the e-LS are further illustrated in Figure 7.5.

PE: Problem Encountered		E1	E2	E3	E4	E5
PE8(3)	Lack of support tools in supporting the process of evaluating and selecting e-Learning software	X	-	X	X	-
PE7(3)	Too dependent on vendors' suggestion	-	-	-	-	-
PE6(2)	Selection process is time consuming	-	-	-	X	X
PE5(2)	Lack of guideline in the evaluation and selection of e-Learning software	-	-	-	X	X
PE4(0)	Difficult to apply current evaluation technique	-	-	-	-	-
PE3(3)	Evaluation criteria consist of uncertain and subjective characteristics	-	X	-	X	X
PE2(3)	Evaluation criteria are unreliable, not fully trustable and risky such as information from internet	-	X	-	X	X
PE1(4)	Lack of information and knowledge about e-Learning software selection criteria	X	-	X	X	X

E: experts

Figure 7.5: Problems Encountered in the Evaluation and Selection of e-LS

In summary, it can be said that not all the experts followed the same stages and processes in evaluating the e-LS. Each expert seemed to have his/her own approach in the evaluation and selection of e-LS. In determining and establishing the evaluation criteria, no specific source was provided. Clearly, organizations rely on the information gathered from the web site through internet surfing, or from the interviews conducted with users. They may also rely on the information gathered from their internal meetings and brainstorming sessions or they may rely on available pamphlets/catalogues/articles/product documentations for information. Sometimes, the information offered by vendors may also be consulted whilst making referrals to the ISO/IEC9126-1 quality factor is another option. However, as can be noted, all these processes are time consuming.

All the five experts considered the criteria of *Functionality* and *Usability* as being Important for the evaluation of the e-LS but as is noticeable in humans, the number of criteria chosen by the experts varied. Some chose a small number of criteria while others selected a bigger number of criteria. This trend suggests that the experts were aware of the importance of these criteria as they were included in the evaluation of the e-LS. It was further observed that most experts preferred to conduct their own internal meetings to gather information while reviewing documentations, pamphlets and articles provided by software providers is another preferred option of the experts. A few experts chose to use the Scoring method in their evaluation while others selected the Benchmark technique, the Rank technique and the Weight method. It was noted that none of the experts considered using the AHP and Fuzzy AHP technique to gather information. The experts also indicated that there was a need to have a supporting tool that can help them in the evaluation process. Finally, it was noted that the problems encountered by the five experts include the unreliability of certain information gathered from the web sites. The other problem was linked to the lack of reliability and trustworthiness of the information gathered from the different sources. The experts also noted that the lack of information and the lack of knowledge about the e-LS selection criteria can hamper their evaluation process. Other problems noted were the uncertain and subjective characteristics that would be difficult to evaluate due to a lack of standard guidelines and the organizations' dependence on vendors may also create a problem when these organizations no longer their services. All of these, whether directly or indirectly concerns money and costs.

7.3 e-LSO: Application of ISQM

This section reports on how the five experts utilized the ISQM in the e-LSO to evaluate the e-LS based on their own goals. The focus of the assessment was on the choice of criteria and the respective sub-criteria selected by the experts to evaluate a number of e-LS alternatives of their own choices. Figures 7.6 to 7.16 will present the results of the criteria, sub-criteria and the e-LS alternatives selected by the experts. In total, 11 criteria were fed into the ISQM framework for experts to select when evaluating the e-LS based on their needs. The number of criteria selected was not constrained. For instance, expert E2 selected the most number of criteria to evaluate the e-LS while expert E3 selected only three criteria.

All the five experts selected *Functionality* and *Usability* as criteria to evaluate an e-LS. Three of the experts selected *Reliability, Efficiency* and *Cost* for their evaluation. One expert selected the *Risk and Uncertainty* criterion but no one selected the *Organizational* criterion for their e-LS evaluation. Coincidentally, *Functionality* and *Usability* were also the two criteria ranked at the top in the Delphi survey while the criteria of *Risk and Uncertainty* and *Organizational* were ranked at the bottom. Figure 7.6 shows the criteria selected by the experts.

	C: Criteria	E1	E2	E3	E4	E5
C11(0)	*Organizational*	-	-	-	-	-
C10(1)	*Risk and Uncertainty*	X	-	-	-	-
C9(1)	*Product Benefit*	-	-	-	X	-
C8(2)	*Vendor*	-	X	-	X	-
C7(3)	*Cost*	-	X	X	X	-
C6(3)	*Efficiency*	X	X	-	X	-
C5(2)	*Portability*	X	X	-	-	-
C4(3)	*Reliability*	X	X	-	-	X
C3(5)	*Usability*	X	X	X	X	X
C2(4)	*Maintainability*	X	X	-	X	X
C1(5)	*Functionality*	X	X	X	X	X

E: Experts

Figure 7.6: Selection of the Evaluation Criteria by Experts

For each of the criterion selected, the experts were also requested to select the respective sub-criteria for use in the evaluation phase. Figure 7.7 shows the experts' selected the sub-criteria of *Functionality*. *Flexibility* and *Suitability* as the two most popular sub-criteria. None of the experts selected *Learning Community* and *Personalization*. Interestingly, *User/Learner Administration* was not identified in the literature but was added by the experts in the Delphi survey; they were also selected by two experts. Experts E1 and E4 selected the mos t number of sub-criteria while Expert E5 selected the least.

SC: Sub-Criteria

		E1	E2	E3	E4	E5
SC10(2)	***User/Learner Administration (New)***	X	-	-	X	-
SC9(1)	*SCORM Compliance*	X	-	-	-	-
SC8(0)	*Learning Community*	-	-	-	-	-
SC7(0)	*Personalization*	-	-	-	-	-
SC6(1)	*Pedagogical*	-	-	-	X	-
SC5(2)	*Interoperability*	-	-	X	X	-
SC4(3)	*Security*	X	X	X	-	-
SC3(5)	*Flexibility*	X	X	X	X	X
SC2(2)	*Accuracy*	-	X	X	-	-
SC1(4)	*Suitability*	X	X		X	X

E: Experts

Figure 7.7: Selection of the Sub-Criteria of *Functionality* by Experts

Figure 7.8 shows that the experts' selected the sub-criteria consisted in *Maintainability*. Expert E1 selected the most (five) sub-criteria while Expert E5 selected the least number of sub-criteria. Expert E3 did not select any of the *Maintainability* sub-criteria but it was noted that *Stability* and *Scalability* were the sub-criteria commonly selected by the experts. None selected the *Expansion* and *Analysability* sub-criteria. Nonetheless, all the experts selected two new sub-criteria of *Error Preventing* and *Fault Software*.

SC: Sub-Criteria

		E1	E2	E3	E4	E5
SC9(2)	***Error Preventing(New)***	X	X	-	-	-
SC8(1)	***Fault Software(New)***	-	X	-	-	-
SC6(0)	***Expansion(New)***	-	-	-	-	-
SC5(2)	*Scalability*	X	X	-	X	-
SC4(2)	*Modularity*	X	X	-	-	-
SC3(1)	*Testability*	X	-	-	X	-
SC2(1)	*Analysability*	-	-	-	-	-
SC1(2)	*Stability*	X	-	-	X	X
SC1(1)	*Changeability*	-	-	-	X	X

E: Experts

Figure 7.8: Selection of the Sub-Criteria of *Maintainability* by Experts

Figure 7.9 shows that the experts' selected the sub-criteria of *Usability*. All the 5 experts selected at least one sub-criterion. Among them, *Customizability* was the most selected sub-criteria while *Learning Content* was not selected at all. E1 selected six sub-criteria while E5 selected only two sub-criteria.

	SC: Sub-Criteria	E1	E2	E3	E4	E5
SC10(1)	***Accessibility Control (New)***	X	-	-	-	-
SC9(0)	Learning Content	-	-	-	-	-
SC8(1)	Learner Interface	-	X	-		-
SC7(2)	Presentation	X	-	-	X	-
SC6(1)	Support tool	-	X	-	-	-
SC5(1)	Hypermediality	X	-	-	-	-
SC4(4)	Customizability	-	X	X	X	X
SC3(3)	Operability	X	-	X	X	-
SC2(3)	Learnability	X	X	X	-	-
SC1(3)	Understand ability	X		X	-	X

E: Experts

Figure 7.9: Selection of the Sub-Criteria of *Usability* by Experts

Figure 7.10 shows that the experts' selected the sub-criteria of *Efficiency* while three experts selected *Memory Capacity* and *Resource Behaviour*. Experts E3 and E5 did not select any sub-criteria.

	SC: Sub-Criteria	E1	E2	E3	E4	E5
SC3(3)	**Memory Capacity (New)**	X	X	-	X	-
SC2(3)	Resource Behaviour	X	X	-	X	-
SC1(3)	Time behaviour	X	-	-	X	-

E: experts

Figure 7.10: Selection of the Sub-Criteria of *Efficiency* by Experts

Figure 7.11 shows that the experts' selected the sub-criteria of *Reliability*. Two experts selected *Maturity*, *Fault Tolerance* and *Backup & Recovery* while only one expert chose *Error Reporting*, a new sub-criterion. Both Experts E2 and E5 selected two sub-criteria while Expert E1 selected three sub-criteria. Experts E3 and E4 did not select any sub-criteria.

SC: Sub-Criteria		E1	E2	E3	E4	E5
SC4(1)	***Error Reporting(New)***	X	-	-	-	-
SC3(2)	*Backup and Recovery*	X	X	-	-	-
SC2(2)	*Fault Tolerance*	-	X	-	-	X
SC1(2)	*Maturity*	X	-	-	-	X

E: Experts

Figure 7.11: Selection of the Sub-Criteria of *Reliability* by Experts

Figure 7.12 shows the selection of the sub-criteria of *Portability*. It was found that only Experts E1 and E2 selected its sub-criteria. Two experts selected *Conformance* and *DBMS Standard* while only one expert selected *Standardability,* the new sub-criteria and *Replaceability*. None selected the *Middleware Standard, Installability* and *Adaptability* sub-criteria. Experts E3, E4 and E5 did not select any sub-criteria under *Portability*.

SC: Sub-Criteria		E1	E2	E3	E4	E5
SC7(1)	***Standardability(New)***	X	-	-	-	-
SC6(0)	*Middleware Standard*	-	-	-	-	-
SC5(2)	*DBMS Standard*	X	X	-	-	-
SC4(2)	*Conformance*	X	X	-	-	-
SC3(1)	*Replaceability*	X	-	-	-	-
SC2(0)	*Installability*	-	-	-	-	-
SC1(0)	*Adaptability*	-	-	-	-	-

E: Experts

Figure 7.12: Selection of the Sub-Criteria of *Portability* by Experts

Figure 7.13 shows the sub-criteria of *Cost*. Three experts selected *Licensing, Implementation*, *Maintenance* and *Training Cost*, two experts selected *Development* and *Upgrading Cost* and only one expert selected *Hardware Cost*. None of the experts selected the new sub-criteria of *Marginal Cost*. Experts E1 and E5 did not select any sub-criteria related to *Cost*.

SC: Sub-Criteria		E1	E2	E3	E4	E5
SC8(0)	***Marginal Cost(New)***	-	-	-	-	-
SC7(3)	*Training Cost*	-	X	X	X	-
SC6(1)	*Hardware Cost*	-	-	X	-	-
SC5(2)	*Upgrading Cost*	-	X	-	X	-
SC4(2)	*Maintenance Cost*	-	X	X	X	-
SC3(3)	*Implementation Cost*	-	X	X	X	-
SC2(2)	*Development Cost*	-	-	X	X	-
SC1(3)	*Licensing Cost*	-	X	X	X	-

E: Experts

Figure 7.13: Selection of the Sub-Criteria of *Cost* of Experts

Figure 7.14 shows the selected sub-criteria of *Vendor*. Only two experts, E2 and E4, selected the sub-criteria in the evaluation phase. One expert selected *Support and Consultancy, Training, Communication* and *Technical & Business Skills*. Two experts selected *Reputation, Services* and Response *Time*. None selected *User Manual, Tutorial*, *Troubleshooting Guide*, *Troubleshooting Guide*, *Demo, Length of Experience* and *Past Business Experience*.

SC: Sub-Criteria		E1	E2	E3	E4	E5
SC14(0)	*Past Business Experience*	-	-	-	-	-
SC13(1)	*Technical and Business Skills*	-	-	-	X	-
SC12(0)	*Length of Experience*	-	-	-	-	-
SC11(2)	*Response Time*	-	X	-	X	-
SC10(0)	*Demo*	-	-	-	-	-
SC9(1)	*Communication*	-	-	-	X	-
SC8(2)	*Maintenance and Upgrading*	-	X	-	X	-
SC7(1)	*Training*	-	X	-	-	-
SC6(0)	*Trouble shooting Guide*	-	-	-	-	-
SC5(0)	*Tutorial*	-	-	-	-	-
SC4(0)	*User Manual*	-	-	-	-	-
SC3(2)	*Services*	-	X	-	X	-
SC2(1)	*Support and Consultancy*	-	-	-	X	-
SC1(2)	*Reputation*	-	X	-	X	-

E: Experts

Figure 7.14: Selection of the Sub-Criteria of *Vendor* by Experts

Figure 7.15 shows the selected sub-criteria of *Product Benefit*. Only Expert E4 selected all the sub- criteria for evaluation.

SC: Sub-Criteria		E1	E2	E3	E4	E5
SC5(1)	*User Satisfaction*	-	-	-	X	-
SC4(1)	*Ease of Use*	-	-	-	X	-
SC3(1)	***User Productivity(New)***	-	-	-	X	-
SC2(1)	***Cost Saving (New)***	-	-	-	X	-
SC1(1)	***After Sales Service (New)***	-	-	-	X	-

E: Experts

Figure 7.15: Selection of the Sub-Criteria of *Product Benefit* by Experts

Finally, Figure 7.16 shows the selection of the sub-criteria of *Risk and Uncertainty*. Only Expert E1 selected the sub-criteria. Two of the new sub-criteria, *Educational System Changed*, and *Software Bugs* were also selected.

SC: Sub-Criteria		E1	E2	E3	E4	E5
SC7(1)	***Educational System Changed(New)***	X	-	-	-	-
SC6(0)	***Unexpected Cost(New)***	-	-	-	-	-
SC5(1)	***Software Bugs (New)***	X	-	-	-	-
SC4(0)	***Frequency of Software Release(New)***	-	-	-	-	-
SC3(1)	*Virus and SPAM*	X	-	-	-	-
SC2(0)	*Product Risk*	-	-	-	-	-
SC1(0)	*Vendor Risk*	-	-	-	-	-

E: Experts

Figure 7.16: Selection of the Sub-Criteria of *Risk and Uncertainty* by Experts

As a whole, it was noted that 10 out of the 11 criteria were selected by the experts in the evaluation phase. The only criterion that they was not selected was *Organizational*. The result of the evaluation process of the e-LSO also looked interesting because, in the Delphi survey, *Organizational* was the last among the criteria ranked by experts according to importance. Another interesting point was that most of the 16 sub-criteria which were added by experts in the Delphi survey were also selected by the experts in this evaluation phase. The 13 new sub-criteria selected by the experts were *User/Learner Administration (Functionality), Error Preventing (Maintainability), Fault Software (Maintainability), Accessibility Control (Usability), Memory Capacity*

(Efficiency), Error Reporting (Reliability), Standardability (Portability), User Productivity (Product Benefit), Cost Saving (Product Benefit), After Sales Service (Product Benefit), Educational System Changed (Risk & Uncertainty), Unexpected Cost (Risk and Uncertainty) and *Software Bugs (Risk & Uncertainty).* This indicates that the sub-criteria proposed by the experts were more practical for use while those suggested by the literature were inadequate for the actual practice of the e-LS evaluation. The results of the survey indicate that the criteria and new sub-criteria obtained in this study were considered important by experts in the evaluation process of e-LS. Besides the criteria and sub-criteria, experts also selected the e-LS alternatives for evaluation. Expert E1 was seeking for an e-LS that was easy to use and so he chose Moodle and Claroline for evaluation. Expert E2 preferred a widely used free software and so he chose Moodle, Web learning, Open Learning and ASP.Net for evaluation. Expert E3 was focusing on the e-LS alternatives that have low implementation cost and likewise, he chose Moodle and WebCT for evaluation. Expert E4 wanted an e-LS that could provide benefit to his organization and he then selected Moodle, Open Learning, Fle 3 and Joomla for evaluation. Expert E5 preferred an e-LS that offer complete support to her organization and so she chose Moodle and Schoology for evaluation. Figure 7.17 shows the e-LS that were selected for evaluation by the experts.

	e-LS: e-Learning Software	E1	E2	E3	E4	E5
e-LS9	ASP.Net	-	X	-	-	-
e-LS8	Joomla	-	-	-	X	-
e-LS7	Schoology	-	-	-		X
e-LS6	Fle 3	-	-	-	X	-
e-LS5	Web CT	-	-	X	-	-
e-LS4	Open Learning	-	X	-	X	-
e-LS3	Web Learning	-	X	-	-	-
e-LS2	Claroline	X	-	-	-	-
e-LS1	Moodle	X	X	X	X	X

E: Experts

Figure 7.17: Selection of e-LS for the Evaluation by Experts

A total of 9 e-LS were selected by the five experts in the evaluation phase. Moodle was the most popular e-LS among the five experts. Experts E2 and E4 evaluated four e-LS products as compared to the others who evaluated only two e-LS products respectively.

7.4 e-LSO: Fuzzy AHP Based Evaluation of e-LS

This section presents the Fuzzy AHP decision model that was constructed by the five experts following the selection of the criteria, sub-criteria and the e-LS alternatives. It begins by looking at the hierarchical structure which composed of the selected criteria, the sub-criteria and the e-LS alternatives. The results of the pairwise comparison judgment of the criteria, sub-criteria and the e-LS alternatives carried out by the experts are shown. Finally, the priority weights of the e-LS alternatives will then be illustrated accordingly. The results drawn from the evaluation done by Experts E3 and E1 will be shown in detail.

7.4.1 Expert E3's Fuzzy AHP Decision Model

a. Hierarchical Structure Representation

Figure 7.18 illustrates the Fuzzy AHP decision model constructed by E3. The model was decomposed into a hierarchical structure which consists of the criteria, sub-criteria and the e-LS alternatives. Level I consist of Goal, Level II consist of three selected criteria including *Functionality, Usability,* and *Cost*. Level III consists of the 14 sub-criteria that were derived from the criteria. Level IV comprises two e-LS namely Moodle and WebCT. Figure 7.18 shows the decision model constructed by Expert E3 that is represented as a hierarchical structure based on the three criteria, 14 sub-criteria and two e-LS alternatives selected for evaluation.

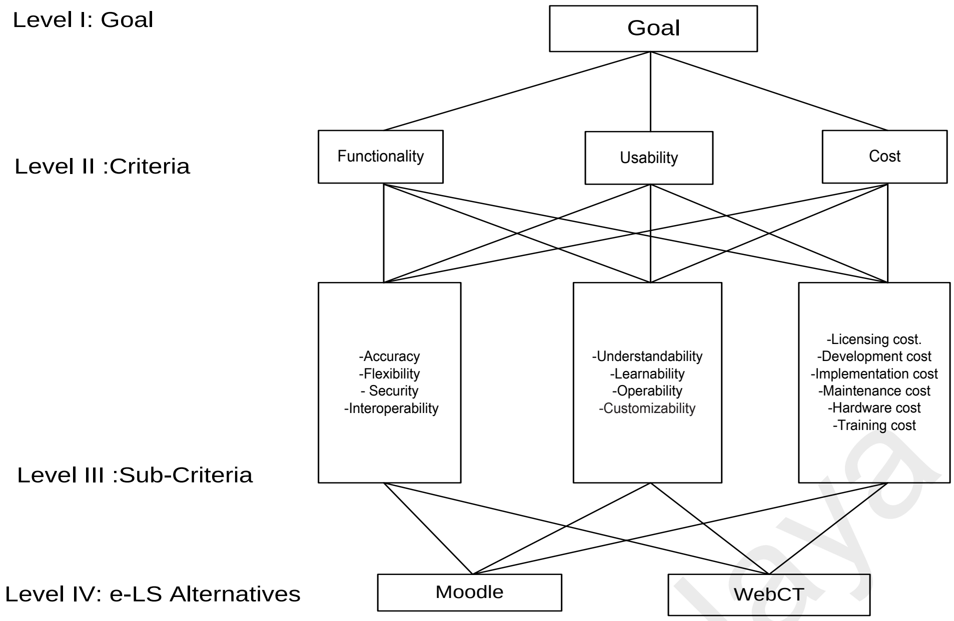


Figure 7.18: Expert E3's Fuzzy AHP Decision Model

b. Pairwise Comparison Judgment of the Selected Criteria (Level II)

Tables 7.1 depict the results of the pairwise comparison judgment of the three criteria of *Functionality*, *Usability* and *Cost*. From the judgment made, the e-LSO converts the linguistic terms into their equivalent Fuzzy numbers. For example, pairwise comparison judgment for *Functionality* and *Cost* is strongly more important based on the linguistic variable that was converted into 3/2, 2, 5/2, as shown in Table 7.1.

Table 7.1: E3's Pairwise Comparison Judgment Matrix of the Selected Criteria

CRITERIA	*Functionality*	*Usability*	*Cost*	Weight
Functionality	1, 1, 1 (Just Equal)	3/2, 2, 5/2 Strongly More Important	3/2, 2, 5/2 (Strongly More Important)	0.728
Usability	2/5, 1/2, 2/3 (Strongly Less Important)	1, 1, 1 Just Equal	1, 3/2, 2 Weakly More Important	0.272
Cost	2/5, 1/2, 2/3 (Strongly Less Important)	1/2, 2/3, 1 (Weakly Less important)	1, 1, 1 (Just Equal)	0.000

Consistency Ratio = 0.00

The extent analysis method provided by the Fuzzy AHP technique by (Chang, 1996) was used to calculate the weights for each of the criteria. The outlines are summarized as follows:

Let $X = \{x_1, x_2, x_3, \dots, x_n\}$ be an object set, and $U = \{u_1, u_2, \dots, u_m\}$ be a goal set.

According to Chang's (1996) extent analysis method, each object is taken and the extent analysis for each goal g_i is performed respectively. Therefore, the m extent analysis values for each object can be obtained and shown as follows:

$$M_{gi}^{1}, M_{gi}^{2}, \dots, M_{gi}^{m}, i = 1, 2, \dots, n \qquad (1)$$

where all the M_{gi}^{j} ($j=1, 2, \dots, m$) are Triangular Fuzzy Numbers (TFNs) whose parameters are l, m, and u. They are the least possible values, the most possible values, and the largest possible values respectively.

A TFN is represented as *(l,m,u)*. The steps of the extent analysis method can be given as follows (Büyüközkan, 2004):

Step 1: The value of fuzzy synthetic extent with respect to the i th object is defined as:

$$S_i = \sum_{j=1}^{m} M_{gi}^{j} \otimes \left[\sum_{j=1}^{n} M_{gi}^{j} \sum_{j=1}^{m} M_{gi}^{j} \right] \qquad (2)$$

To obtain $\sum_{j=1}^{m} M_{gi}^{j}$, the fuzzy addition operation of m extent analysis values for a particular matrix is performed such that:

$$\sum_{j=1}^{m} M_{gi}^{j} = \left[\sum_{j=1}^{m} l_{ij} \; \sum_{j=1}^{m} M_{ij} \; \sum_{j=1}^{m} U_{ij}\right]^{-1} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

and to obtain $\left[\sum_{j=1}^{n} \; \sum_{j=1}^{m} \; \sum_{j=1}^{m} M_{gi}^{j}\right]^{-1}$ we perform the fuzzy addition operation

of N_{gi}^{j} $(j = 1; 2, \ldots ,m)$ values such that:

$$\sum_{\mathrm{i}=1}^{\mathrm{n}} \; \sum_{j=1}^{m} M_{gi}^{j} = \left[\sum_{j=1}^{n} l_{ij}, \sum_{j=1}^{n} M_{ij}, \sum_{j=1}^{n} U_{ij}\right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

Where

$$l_i = \sum_{j=1}^{m} l_{y} \quad , \; m_i = \sum_{j=1}^{m} m_{ij} \quad , u_i = \sum_{j=1}^{m} u_{ij}$$

Then, the inverse of the vector in equation (5) is computed as:

$$\left[\sum_{j=1}^{n} \; \sum_{j=1}^{n} M_{gi}^{j}\right]^{-1} = \left[\frac{1}{\sum_{i=1}^{n} u_{i}}, \frac{1}{\sum_{i=1}^{n} m_{i}}, \frac{1}{\sum_{i=1}^{n} l_{i}}\right] \ldots\ldots\ldots(5)$$

Where

$\forall u_i, m_i, l_i \; > 0$

Finally, to obtain the S_{i} in equation (2), the following multiplication is performed:

$$S_{\mathrm{i}} = \sum_{j=1}^{m} M_{gi}^{j} \otimes \left[\sum_{j=1}^{n} \; \sum_{j=1}^{n} M_{gi}^{j}\right]^{-1}$$

$$= \left[\sum_{j=1}^{m} l_{ij} \; X \; \frac{1}{\sum_{i=1}^{n} m_{i}}, \sum_{j=1}^{m} U_{ij} \; X \; \frac{1}{\sum_{i=1}^{n} l_{i}}\right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(6)$$

Step 2: The degree of possibility of $M_2 = (l_2, m_2, u_2) \geq M_1 = (l_1, m_1, u_1)$ is defined as:

$$V(M_2 \geq M_1 = \sup_{y \geq x}[\min(\mu_{M_1}(x), \mu_{M_2}(y))] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(7)$$

which can be expressed equivalently as follows

$$V(M_2 \geq M_1) = hgt(M_1 \cap M_2) = \mu_{M_2}(d) = \begin{cases} 1 & \text{if } m_2 \geq m_1 \\ 0 & \text{if } l_1 \geq l_2 \\ \dfrac{(l1 - u2)}{(m_2 - u_2) - (m_1 - u_1)}, & \text{otherwise} \end{cases} \ldots(8)$$

where d is the ordinate of the highest intersection point D between μ_{M_1} and μ_{M_2}

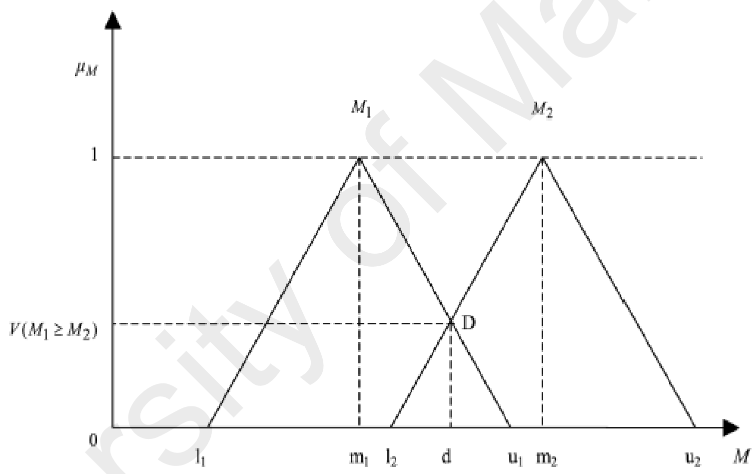


Figure 7.19: The Intersection Between M_1 and M_2

To compare M_1 and M_2, we need both the values of $V(M_1 \geq M_2)$ and $V(M_2 \geq M_1)$. The intersection between M_1 and M_2 is shown in Figure 7.19.

Step 3: The degree possibility for a convex fuzzy number to be greater than k convex fuzzy numbers Mi $(i = 1, 2, \ldots, k)$ can be defined by:

$$V(M \geq M_1, M_2, \ldots, M_k) = V[(M \geq M_2) \text{ and } (M \geq M_2) \text{ and } \ldots \text{ and } M \geq M_k] =$$

$$\min V(M \geq M_i);\ i = 1, 2, \ldots, k: \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(9)$$

Assuming that

$D'(S_i) = min\ V(S_i \geq S_k)$ ……………………………………………..……..……..(10)

For $k = 1, 2, . . . , n; k \neq i$. Then the weight vector is given by:

$W'(S_i) = D'(S_1), D'(S_2), \ldots.., D'(S_n)^T$ ………………………………………..……..…….(11)

where $Si\ (i = 1, 2, . . . , n)$ are n elements.

Step 4: The normalization

The elements in each resulting row are added. This sum is divided by the number of elements in the row. The normalized weight vectors are obtained as follows:

$W = D(S_1), D(S_2), \ldots, D(S_n)^T$ where W is not a fuzzy number ………….(12)

Consistency issues in pairwise comparison using Fuzzy AHP technique is another subject that needs to be examined (Perçin, 2008).

The Consistency Ratio (CR) is calculated using the following steps:

Step i: Compute the consistency index for each matrix of order n by using formula:

Consistency Index (CI)= (λmax-n) / (n-1)

where *λmax* the largest eigenvalue of the comparison matrix n is the number of items being compared in the matrix, and RI is a random index (Perçin, 2008). RI has been shown in Table 2.4 in Chapter 2.

Step ii. The CR is then calculated using the formula:

$CR = CI / RI$ ……..………..……….…………………….…………………… (13)

The consistency of each matrix is considered acceptable if the $CR \leq 0.1$ (Saaty, 2000; Hsieh et al., 2015).

The calculation of the weight criteria using Fuzzy AHP technique is explained as follow:

Step i: Using formula (2), (3), (4), (5) and (6) as in page 231 and 232, calculate the Matrix to obtain the average value

$S_{Functionlity}=(1+3/2+3/2,\ 1+2+2,\ 1+5/2 + 5/2) *$

$(1/(1+5/2+5/2+2/3+1+2+2/3+1+1),\ 1/(1+2+2+1/2+1+3/2+1/2+2/3+1),$

$1/((1+3/2 + 3/2 + 2/5+ 1 + 1 +2/5 + 1/2 +1))$

$S_{Functionlity}=(4, 5, 6) * (1/12.3334, 1/10.1667, 1/8.3)$

$S_{Functionlity}= (0.324, 0.492, 0.723)$

$S_{Usability} = (2/5 +1+ 1,\ 1/2 +1+ 3/2,\ 2/3 + 1+2) *$

$(1/(1+5/2+5/2+2/3+1+2+2/3+1+1),\ 1/(1+2+2+1/2+1+3/2+1/2+2/3+1),$

$1/((1+3/2 + 3/2 + 2/5+ 1 + 1 +2/5 + 1/2 +1))$

$S_{Usability} = (2.4, 3, 3.6667) * (1/12.3334, 1/10.1667, 1/8.3)$

$S_{Usability}= (0.195, 0.295, 0.442)$

$S_{Cost} = (2/5 + 1/2 + 1,\ 1/2 +2/3 +1,\ 2/3 +1+ 1) *$

$(1/(1+5/2+5/2+2/3+1+2+2/3+1+1),\ 1/(1+2+2+1/2+1+3/2+1/2+2/3+1),$

$1/((1+3/2 + 3/2 + 2/5+ 1 + 1 +2/5 + 1/2 +1))$

$S_{Cost} = (1.9, 2. 167, 2.667) * (1/12.333, 1/10.167, 1/8.3)$

$S_{Cost} = (0.154, 0.213, 0.321)$

Step ii: Using formula (7), (8), (9), (10) as in page 233 and 234, the minimum (Min) is determined.

$V(S_{Functionlity} > = S_{usability)} = 1$

$V(S_{Functionlity} > = S_{cost}) = 1$

$Min\ S_{Functionlity} = 1$

$V(S_{Usability} > = S_{Functionlity)} = 0.374$

$V(S_{Usability} > = S_{cost}) = 1$

$Min\ S_{Usability} = 0.374$

$V(S_{Cost} > = S_{Functionlity}) = 0$

$V(S_{Cost} > = S_{usability}) = 0.607$

$Min\ S_{Cost} = (0,0.607) = 0$

Step iii: Normalization can be done using formula (11), step 4, and formula (12) as in page 234 to obtain the weight:

Weight for *Functionality* $= 1 / (1+0.374 + 0)$

$= 0.728$

Weight for *Usability* $= 0.374 /(1+0.374 + 0)$

$= 0.272$

Weight for *Cost* $= 0 / (1+0.374 + 0)$

$= 0.000$

The same calculation steps were used to obtain the weights for the sub-criteria and e-LS alternatives.

c. E3's Pairwise Comparison Judgment of the Sub-Criteria (Level III)

Expert E3 has compared each sub-criterion of *Functionality* over another to obtain the sub-criteria weight. Table 7.2 shows the weight of the pairwise comparison judgment matrix for the *Functionality* sub-criteria, as selected by Expert E3.

Table 7.2: E3's Pairwise Comparison Judgment Matrix for the *Functionality* Sub-Criteria

SUB-CRITERIA	*Accuracy*	*Flexibility*	*Security*	*Interoperability*	Weight
Accuracy	1,1,1	3/2,2,5/2	2,5/2,3	2,5/2,3	0.709
Flexibility	2/5,1/2,2/3	1,1,1	1,3/2,2	1,3/2,2	0.240
Security	1/3,2/5,1/2	1/2,2/3,1	1,1,1	1,3/2,2	0.051
Interoperability	1/3,2/5,1/2	1/2,2/3,1	1/2,2/3,1	1,1,1	0.000

Consistency Ratio = 0.0396

Expert E3 compared each sub-criterion of *Usability* over another to obtain the sub-criteria weight. Table 7.3 shows the weight of the pairwise comparison judgment matrix for the *Usability* sub-criteria, as selected by E3.

Table 7.3: E3's Pairwise Comparison Judgment Matrix for the *Usability* Sub-Criteria

SUB-CRITERIA	*Understandability*	*Learnability*	*Operability*	*Customizability*	Weight
Understandability	1,1,1	3/2,2,5/2	2,5/2,3	5/2,3,7/2	0.697
Learnability	2/5,1/2,2/3	1,1,1	3/2,2,5/2	3/2,2,5/2	0.303
Operability	1/3,2/5,1/2	2/5,1/2,2/3	1,1,1	1,3/2,2	0.000
Customizability	2/7,1/3,2/5	2/5,1/2,2/3	1/2,2/3,1	1,1,1	0.000

Consistency Ratio = 0.0346

Expert E3 compared each sub-criterion of *Cost* over another to obtain the sub-criteria weight. Table 7.4 shows the weight of the pairwise comparison judgment matrix for the *Cost* sub-criteria, as selected by E3.

Table 7.4: E3's Pairwise Comparison Judgment Matrix for the *Cost* Sub-Criteria

SUB-CRITERIA	*Licensing Cost*	*Development Cost*	*Implementation Cost*	*Maintenance Cost*	*Training Cost*	*Hardware Cost*	Weight
Licensing Cost	1,1,1	3/2,2,5/2	2,5/2,3	3/2,2,5/2	2,5/2,3	2,5/2,3	0.458
Development Cost	2/5,1/2,2/3	1,1,1	1,3/2,2	1,3/2,2	1,3/2,2	3/2,2,5/2	0.245
Implementation Cost	1/3,2/5,1/2	1/2,2/3,1	1,1,1	3/2,2,5/2	1,3/2,2	1,3/2,2	0.185
Maintenance Cost	2/5,1/2,2/3	1/2,2/3,1	2/5,1/2,2/3	1,1,1	1,3/2,2	1,3/2,2	0.085
Hardware Cost	1/3,2/5,1/2	1/2,2/3,1	1/2,2/3,1	1/2,2/3,1	1,1,1	1,3/2,2	0.000
Training Cost	1/3,2/5,1/2	2/5,1/2,2/3	1/2,2/3,1	1/2,2/3,1	1/2,2/3,1	1,1,1	0.027

Consistency Ratio = 0.0407

Table 7.1 - Table 7.4 show the weight of the pairwise comparison judgment with respect to the criteria and sub-criteria, as selected by E3. The consistency of each matrix is considered acceptable if the $CR \leq 0.1$ (Saaty, 2000; Hsieh et al., 2015). This indicates the consistency in Expert E3's pairwise comparison judgment. Therefore, the

weight result of the criteria and the sub-criteria in the E3's pairwise comparison can be reasonably accepted since $CR \leq 0.1$.

d. E3's Pairwise Comparison Judgment for Criteria and Sub-Criteria

This section summarizes the result of the pairwise comparison judgment for the criteria and sub-criteria. They are shown in Table 7.5.

Table 7.5: The Overall of E3's Pairwise Comparison Judgment Weight for Each Criterion and Sub-Criterion of the e-LS

Criteria	**Weight**	**Sub-Criteria**	**Weight**
Functionality	0.728	*Accuracy*	0.709
		Flexibility	0.240
		Security	0.051
		Interoperability	0.000
Usability	0.272	*Understandability*	0.697
		Learnability	0.303
		Operability	0.000
		Customizability	0.000
Cost	0.000	*Licensing Cost*	0.458
		Development Cost	0.245
		Implementation Cost	0.185
		Maintenance Cost	0.085
		Hardware Cost	0.000
		Training Cost	0.027

e. E3's Pairwise Comparison of the e-LS Alternatives (Level IV)

In the following step of the evaluation procedure, the e-LS alternatives were compared with respect to each sub-criterion, separately. E3 has chosen two e-LS alternatives namely Moodle and Web CT for comparison. Results for the pairwise comparison judgment by E3 are shown in Table 7.6.

Table 7.6: The Overall Pairwise Comparison Judgment Weight for the Evaluation of the e-LS Alternative With Respect to Each Sub-Criterion of the e-LS by E3

Evaluation of e-LS alternative	**Weight**	
Sub-Criteria	Moodle	Web CT
Evaluation e-LS alternative with respect to *Accuracy*	1.000	0.000
Evaluation e-LS alternative with respect to *Flexibility*	1.000	0.000
Evaluation e-LS alternative with respect to *Security*	0.684	0.316
Evaluation e-LS alternative with respect to *Interoperability*	1.000	0.000
Evaluation e-LS alternative with respect to *Understandability*	1.000	0.000
Evaluation e-LS alternative with respect to *Learn ability*	1.000	0.000
Evaluation e-LS alternative with respect to *Operability*	1.000	0.000
Evaluation e-LS alternative with respect to *Customizability*	1.000	0.000
Evaluation e-LS alternative with respect to *Licensing Cost*	1.000	0.000
Evaluation e-LS alternative with respect to *Development Cost*	1.000	0.000
Evaluation e-LS alternative with respect to *Implementation Cost*	1.000	0.000
Evaluation e-LS alternative with respect to *Maintenance Cost*	1.000	0.000
Evaluation e-LS alternative with respect to *Hardware Cost*	1.000	0.000
Evaluation e-LS alternative with respect to *Training Cost*	1.000	0.000

f. E3’s Final Scores of e-LS Alternatives

The final computation was made to obtain the priority weight of E3’s e-LS alternatives. This was done by obtaining the weights over the hierarchy for each e-LS alternative. To obtain this, the weight along the path from the top of the hierarchy was multiplied to a decision alternative (Perçin, 2008). In this case, the decision alternatives are the e-LS alternatives. These results were then summed up over all the different pathways to those of the e-LS alternatives. To determine the final priority, the weight of each alternative is calculated by combining the weights for the criteria, sub-criteria and the e-LS alternatives (Büyüközkan, 2004).

The overall weight calculation is:

Overall weight Moodle = *([(0.728 * 0709 * 1) + (0.728 * 0.24 * 1) + (0.728 * 0.051 * 0.684) + (0.728 * 0 * 1)] +[(0.272 * 0.697 * 1) + (0.272 * 0.303 * 1) + (0.272 * 0 * 1) + (0.272 * 0 * 1)] +[(0 * 0.458 * 1) + (0 * 0.245 * 1) + (0 * 0.185 * 1) + (0 * 0.085 * 1)+ (0 * 0 * 1) + (0 * 0.027 * 1)])*

Overall Weight Moodle = 0.988

*Overall weight Web CT = ([(0.728 * 0709 * 0) + (0.728 * 0.24 * 0) + (0.728 * 0.051 * 0.316) + (0.728 * 0 * 0)] +[(0.272 * 0.697 * 0) + (0.272 * 0.303 * 0) + (0.272 * 0 * 0) + (0.272 * 0 * 0)] +[(0 * 0.458 * 0) + (0 * 0.245 * 0) + (0 * 0.185 * 0) + (0 * 0.085 * 1)+ (0 * 0 * 0) + (0 * 0.027 * 0)])*

Overall weight Web CT = 0.012

The final score results can then be ascertained from the final priority weights, as presented in Table 7.7.

Table 7.7: Final Scores of the e-LS Alternatives by E3

e-LS	Overall Weight
Moodle	0.988
Web CT	0.012

7.4.2 Expert E1's Fuzzy AHP Decision Model

a. E1's Hierarchical Structure Representation

Figure 7.19 shows the Fuzzy AHP decision model constructed by E1. The model is decomposed into a hierarchical structure consisting of the criteria, sub-criteria and the e-LS alternatives. The Goal is defined in Level I. Level II consists of seven criteria that were selected by E1 including *Functionality, Maintainability, Usability,* *Reliability, Efficiency* and *Risk and Uncertainty*. Level III consists of 30 sub-criteria that were derived from the criteria. Level IV comprises two chosen e-LS namely, Moodle and Caroline.

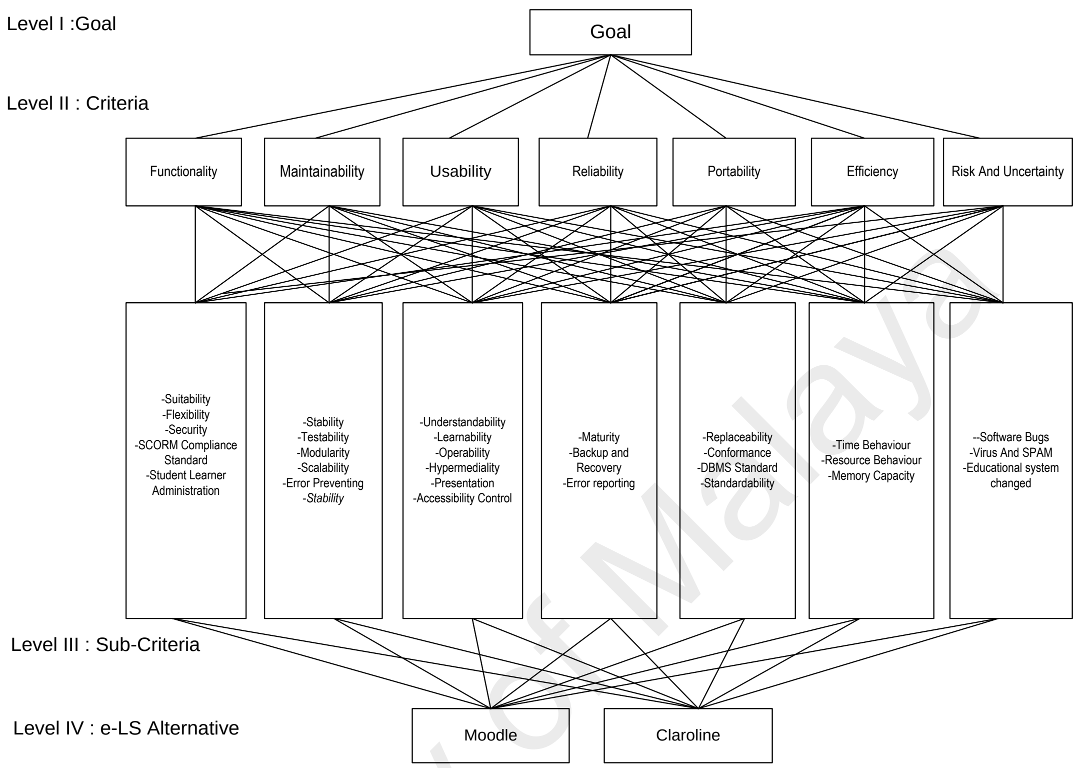


Figure 7.20: Expert E1's Fuzzy AHP Decision Model

Each criterion, sub-criterion and e-LS was evaluated by E1 using the e-LSO. The following shows the results of the pairwise comparison judgment of the e-LS criteria, sub-criteria and the e-LS alternatives, for Expert E1.

b. E1's Pairwise Comparison Judgment of the Selected Criteria (Level II)

Table 7.8 shows the pairwise comparison judgment matrix selected by E1. Each criterion was compared over another and then given judgment so as to obtain the criteria weight.

Table 7.8: E1's Pairwise Comparison Judgment Matrix of the Selected Criteria

CRITERIA	*Functionality*	*Maintainability*	*Usability*	*Reliability*	*Portability*	*Efficiency*	*Risk and Uncertainty*	Weight
Functionality	1,1,1	1/2,1,3/2	3/2,2,5/2	2,5/2,3	1,3/2,2	2,5/2,3	2,5/2,3	0.248
Maintainability	2/3,1,2	1,1,1	2,5/2,3	3/2,2,5/2	1/2,2/3,1	1,3/2,2	1,3/2,2	0.196
Usability	2/5,1/2,2/3	1/3,2/5,1/2	1,1,1	1/2,1,3/2	2/3,1,2	3/2,2,5/2	1/2,1,3/2	0.119
Reliability	1/3,2/5,1/2	2/5,1/2,2/3	2/3,1,2	1,1,1	1,3/2,2	1/2,1,3/2	2,5/2,3	0.143
Portability	1/2,2/3,1	1,3/2,2	1/2,1,3/2	1/2,2/3,1	1,1,1	3/2,2,5/2	2/3,1,2	0.146
Efficiency	1/3,2/5,1/2	1/2,2/3,1	2/5,1/2,2/3	2/3,1,2	2/5,1/2,2/3	1,1,1	1/2,1,3/2	0.06
Risk and Uncertainty	1/3,2/5,1/2	1/2,2/3,1	2/3,1,2	1/3,2/5,1/2	1/2,1,3/2	2/3,1,2	1,1,1	0.087

Consistency Ratio = 0.0836

c. E1's Pairwise Comparison Judgment for the Sub-Criteria of the e-LS (Level III)

Table 7.9 shows the weight of the pairwise comparison judgment matrix with respect to the sub-criteria of *Functionality*. Each sub-criterion of *Functionality* was compared over another and then given judgment so as to obtain the sub-criteria weights.

Table 7.9: E1's Pairwise Comparison Judgment Matrix for the *Functionality* Sub-Criteria

SUB-CRITERIA	*Suitability*	*Flexibility*	*Security*	*SCORM Compliance*	*Student / Learner Administration*	Weight
Suitability	1,1,1	5/2,3,7/2	2,5/2,3	2,5/2,3	2,5/2,3	0.528
Flexibility	2/7,1/3,2/5	1,1,1	1,3/2,2	3/2,2,5/2	5/2,3,7/2	0.251
Security	1/3,2/5,1/2	1/2,2/3,1	1,1,1	5/2,3,7/2	2,5/2,3	0.221
SCORM Compliance	1/3,2/5,1/2	2/5,1/2,2/3	2/7,1/3,2/5	1,1,1	3/2,2,5/2	0.000
User/Learner Administration	1/3,2/5,1/2	2/7,1/3,2/5	1/3,2/5,1/2	2/5,1/2,2/3	1,1,1	0.000

Consistency Ratio = 0.0836

The sub-criteria of *Maintainability* were compared over another sub-criteria and then given judgments so as to obtain the sub-criteria weights. Table 7.10 shows the weights of the pairwise comparison judgment with respect to the *Maintainability* sub-criteria.

Table 7.10: E1's Pairwise Comparison Judgment Matrix for the *Maintainability* Sub-Criteria

SUB-CRITERIA	*Stability*	*Testability*	*Modularity*	*Scalability*	*Error Preventing*	Weight
Stability	1,1,1	5/2,3,7/2	2,5/2,3	3/2,2,5/2	3/2,2,5/2	0.479
Testability	2/7,1/3,2/5	1,1,1	3/2,2,5/2	2,5/2,3	2,5/2,3	0.339
Modularity	1/3,2/5,1/2	2/5,1/2,2/3	1,1,1	3/2,2,5/2	2,5/2,3	0.182
Scalability	2/5,1/2,2/3	1/3,2/5,1/2	2/5,1/2,2/3	1,1,1	1/2,1,3/2	0.000
Error Preventing	2/5,1/2,2/3	1/3,2/5,1/2	1/3,2/5,1/2	2/3,1,2	1,1,1	0.000

Consistency Ratio = 0.0899

Each sub-criterion of *Usability* was compared over another and then given judgment so as to obtain the sub-criteria weights. Table 7.11 shows the weight of E1's pairwise comparison judgment with respect to the *Usability* sub-criteria as made by E1.

Table 7.11: E1's Pairwise Comparison Judgment Matrix for the *Usability* Sub-Criteria

SUB-CRITERIA	*Understandability*	*Learnability*	*Operability*	*Hypermediality*	*Presentation*	*Accessibility Control or Privilege*	Weight
Understandability	1,1,1	5/2,3,7/2	2,5/2,3	3/2,2,5/2	3/2,2,5/2	2,5/2,3	0.442
Learnability	2/7,1/3,2/5	1,1,1	2,5/2,3	2,5/2,3	3/2,2,5/2	2,5/2,3	0.338
Operability	1/3,2/5,1/2	1/3,2/5,1/2	1,1,1	2,5/2,3	2,5/2,3	3/2,2,5/2	0.219
Hypermediality	2/5,1/2,2/3	1/3,2/5,1/2	1/3,2/5,1/2	1,1,1	3/2,2,5/2	1/2,1,3/2	0.000
Presentation	2/5,1/2,2/3	2/5,1/2,2/3	1/3,2/5,1/2	2/5,1/2,2/3	1,1,1	1,1,1	0.000
Accessibility Control or Privilege	1/3,2/5,1/2	1/3,2/5,1/2	2/5,1/2,2/3	2/3,1,2	1,1,1	1,1,1	0.000

Consistency Ratio = 0.0802

Each sub-criterion of *Efficiency* was compared over another and then given judgment so as to obtain the sub-criterion weights. Table 7.12 shows the weight of the pairwise comparison judgment with respect to the sub-criteria of *Usability* as made by E1.

Table 7.12: E1's Pairwise Comparison Judgment Matrix for the *Efficiency* Sub-Criteria

SUB-CRITERIA	*Time behavior*	*Resource behavior*	*Memory capacity*	Weight
Time Behavior	1,1,1	3/2,2,5/2	2,5/2,3	0.732
Resource Behavior	2/5,1/2,2/3	1,1,1	3/2,2,5/2	0.268
Memory Capacity	1/3,2/5,1/2	2/5,1/2,2/3	1,1,1	0.000

Consistency Ratio = 0.0582

Each sub-criterion of *Reliability* was compared over another and then given judgment so as to obtain the sub-criterion weights. Table 7.13 shows the weight of the pairwise comparison judgment with respect to the *Reliability* sub-criteria as selected by E1.

Table 7.13: E1's Pairwise Comparison Judgment Matrix for the *Reliability* Sub-Criteria

SUB-CRITERIA	*Maturity*	*Backup and Recovery*	*Error Preventing*	Weight
Maturity	1,1,1	2,5/2,3	2,5/2,3	0.933
Backup and Recovery	1/3,2/5,1/2	1,1,1	2/3,1,2	0.067
Error Preventing	1/3,2/5,1/2	1/2,1,3/2	1,1,1	0.000

Consistency Ratio = 0.087

Each sub-criterion of *Portability* was compared over another and then given judgment so as to obtain the sub-criterion weights. Table 7.14 shows the weight of the pairwise comparison judgment with respect to the *Portability* sub-criteria as selected by E1.

Table 7.14: E1's Pairwise Comparison Judgment Matrix for the *Portability* Sub- Criteria

SUB-CRITERIA	*Replaceability*	*Conformance*	*DBMS Standard*	*Standardability*	Weight
Replaceability	1,1,1	3/2,2,5/2	2,5/2,3	5/2,3,7/2	1.000
Conformance	2/5,1/2,2/3	1,1,1	1,1,1	1,3/2,2	0.000
DBMS Standard	1/3,2/5,1/2	1,1,1	1,1,1	2/3,1,2	0.000
Standardability	2/7,1/3,2/5	1/2,2/3,1	1/2,1,3/2	1,1,1	0.000

Consistency Ratio = 0.0393

Each sub-criterion of *Risk and Uncertainty* was compared over another and then given judgment so as to obtain the sub-criterion weights. Table 7.15 shows the weight of the pairwise comparison judgment with respect to the *Risk and Uncertainty* sub-criteria as selected by E1.

Table 7.15: E1's Pairwise Comparison Judgment Matrix for the *Risk and Uncertainty* Sub-Criteria

SUB-CRITERIA	*Software Bugs and Errors*	*Virus and SPAM*	*Educational System Change*	Weight
Software Bugs and Errors	1,1,1	5/2,3,7/2	3/2,2,5/2	0.734
Virus and SPAM	2/7,1/3,2/5	1,1,1	1/3,2/5,1/2	0.000
Educational System Change	2/5,1/2,2/3	2,5/2,3	1,1,1	0.266

Consistency Ratio = 0.0546

Tables 7.8 - Table 7.15 show the weights of the pairwise comparison judgment with respect to the criteria and sub-criteria selected by Expert E1. The consistency of each matrix is considered acceptable if the $CR \leq 0.1$ (Saaty, 2000; Hsieh et al., 2015). This indicates the consistency in E1's pairwise comparison judgment. Therefore, the weight result of the criteria and sub-criteria in E1's pairwise comparison can be reasonably accepted since $CR \leq 0.1$.

d. E1's Pairwise Comparison Judgment for Criteria and Sub-Criteria

The overall weight on the pairwise comparison judgment for the criteria and sub-criteria selected by E1 is shown in Table 7.16.

Table 7.16: Overall Weight for Pairwise Comparison Judgment by E1

Criteria (Level 1)	Weight	Sub-Criteria (Level III)	Weight
Functionality	0.248	*Suitability*	0.528
		Flexibility	0.251
		Security	0.221
		SCORM Compliance	0.000
New Sub-Criteria		***Student/Learner Administration***	***0.000***
Maintainability	0.196	*Stability*	0.479
		Testability	0.339
		Modularity	0.182
		Scalability	0.000
		Error Preventing	0.000
New Sub-Criteria		***Stability***	***0.479***
Usability	0.119	*Understandability*	0.442
		Learnability	0.338
		Operability	0.219
		Hypermediality	0.000
		Presentation	0.000
New Sub-Criteria		***Accessibility Control or Privilege***	***0.000***
Efficiency	0.143	*Time Behaviour*	0.732
		Resource Behaviour	0.268
New Sub-Criteria		***Memory Capacity***	***0.000***
Reliability	0.146	*Maturity*	0.933
		Backup and Recovery	0.067
		Error Reporting	*0.000*
Portability	0.060	*Replaceability*	1.000
		Conformance	0.000
		DBMS Standard	0.000
New Sub-Criteria		***Standardability***	***0.000***
Risk and Uncertainty	0.087	*Software Bugs and Errors*	0.734
		Virus and SPAM	0.000
		Educational System Changed	*0.266*

e. E1's Pairwise Comparison of the e-LS Alternatives (Level IV)

In this step of the evaluation procedure, the e-LS alternatives were compared to each sub-criterion separately. E1 has chosen two alternatives namely, Moodle and Caroline, to be considered for the comparison. Results for the pairwise comparison judgment for the e-LS alternatives, with respect to each sub-criterion, are shown in Table 7.17.

Table 7.17: Pairwise Comparison Judgment Weight for the Evaluation of the e-LS Alternatives With Respect to Each Sub-Criterion of the e-LS by E1

Evaluation of e-LS alternative	**Weight**	
	Moodle	Caroline
Evaluation e-LS alternative with respect to *Suitability*	0.500	0.500
Evaluation e-LS alternative with respect to *Flexibility*	1.000	0.000
Evaluation e-LS alternative with respect to *Security*	1.000	0.000
Evaluation e-LS alternative with respect to *SCORM Compliance*	0.500	0.500
Evaluation e-LS alternative with respect to *User/Learner Administration*	0.500	0.500
Evaluation e-LS alternative with respect to *Stability*	0.684	0.316
Evaluation e-LS alternative with respect to *Testability*	0.500	0.500
Evaluation e-LS alternative with respect to *Modularity*	0.500	0.500
Evaluation e-LS alternative with respect to *Scalability*	1.000	0.000
Evaluation e-LS alternative with respect to *Error Preventing*	1.000	0.000
Evaluation e-LS alternative with respect to *Understandability*	1.000	0.000
Evaluation e-LS alternative with respect to *Learn ability*	1.000	0.000
Evaluation e-LS alternative with respect to *Operability*	1.000	0.000
Evaluation e-LS alternative with respect to *Hypermediality*	0.500	0.500
Evaluation e-LS alternative with respect to *Presentation*	0.684	0.316
Evaluation e-LS alternative with respect to *Accessibility Control or Privilege*	1.000	0.000
Evaluation e-LS alternative with respect to *Time Behaviour*	0.684	0.316
Evaluation e-LS alternative with respect to *Resource Behaviour*	1.000	0.000
Evaluation e-LS alternative with respect to *Memory Capacity*	0.500	0.500
Evaluation e-LS alternative with respect to *Maturity*	0.316	0.684
Evaluation e-LS alternative with respect to *Backup and Recovery*	1.000	0.000
Evaluation e-LS alternative with respect to *Erro r Reporting*	1.000	0.000
Evaluation e-LS alternative with respect to *Replaceability*	1.000	0.000
Evaluation e-LS alternative with respect to *Conformance*	0.500	0.500
Evaluation e-LS alternative with respect to *DBMS Standard*	1.000	0.000
Evaluation e-LS alternative with respect to *Standardability*	1.000	0.000
Evaluation e-LS alternative with respect to *Software Bugs and Errors*	1.000	0.000
Evaluation e-LS alternative with respect to *Virus and SPAM*	1.000	0.000
Evaluation e-LS alternative with respect to *Educational System Changed*	0.500	0.500

f. E1's Final Scores of the e-LS Alternatives

The final computation was made to obtain the priority weight of E1's e-LS alternatives. This was done by obtaining the weights over the hierarchy for each e-LS alternative. To obtain this, the weight along the path, from the top of the hierarchy, was multiplied to a decision alternative (Perçin, 2008). These results were then summed up over all the different pathways to those of the e-LS alternatives. To determine the final priority, the weight of each alternative is calculated by combining the weights for the criteria, sub-criteria and the e-LS alternatives (Büyüközkan, 2004). The final score results can be ascertained from the final priority weights, as presented in Table 7.18.

Table 7.18: Final Scores of the e-LS Alternatives by E1

e-LS	**Overall Weight**
Moodle	0.726
Claroline	0.273

The overall weight shows that Claroline has a relatively low score as compared to Moodle. Thus, it can be concluded that Moodle was the preferred e-LS product for the goal and criteria defined by E1. The results for E2, E4 and E5 are attached in Appendix K.

Based on the usability evaluation of the e-LSO as provided by the selected five experts, it appears that nine new sub-criteria could be used for selection. These sub-criteria include *User/Learner Administration*, *Fault Software*, *Error Preventing, Error reporting, Memory Capacity, User productivity, Cost Saving, After Sales Services*, *Software Bugs* and *Educational System and Changed*. Therefore, it is deduced that these nine new sub-criteria were considered important for the evaluation of the e-LS.

The number of criteria and sub-criteria chosen varied from one expert to another. The overall criteria selected by the experts in the evaluation phase can be seen in Appendix K. Table 7.19 summarizes the number of criteria, sub-criteria and e-LS alternatives selected by the experts.

Table 7.19: The Summary of Criteria, Sub-Criteria and e-LS

Experts	Number of Criteria	Number of Sub-Criteria	Number of e-LS
E1	7	30	2
E2	8	28	4
E3	3	14	2
E4	7	33	4
E5	4	8	2

Based on Table 7.19, it appears that Experts E1, E2, E3, E4 and E5 have their own perspective on which criteria, sub-criteria, or e-LS should be selected. From the list of 11 criteria and 81 sub-criteria, the experts had chosen only those which they believed to be important based on their needs, in the evaluation of the e-LS. Thus, it can be seen that the selection of criteria and sub-criteria would vary from one expert to another.

Nevertheless, the large list of criteria and sub-criteria provided in the e-LSO has offered the experts a wide choice in selecting the criteria, sub-criteria and the e-LS. Organizations could therefore, develop their own Fuzzy AHP decision model based on those criteria, sub-criteria and e-LS alternatives provided by the e-LSO database, for their respective evaluation purposes.

7.5 e-LSO: Usability Evaluation

This section will report the usability evaluation result. As explained in Section 3.5.3.2, upon the completion of the e-LSO evaluation, the experts were asked to fill the usability questionnaire as a means to evaluate the usability of the e-LSO. This result will be discussed below. After completing the usability evaluation of the e-LSO, the experts were also interviewed and requested to answer several questions, as attached in Appendix I.

7.5.1 Usability Evaluation Results

In order to analyze the result, the mean average rating was analyzed and used. The mean rating was also recommended by Ricchi and Nguyen (2007) and Jadhav and Sonar (2011) in their usability evaluation works of the software tool.

In relation to the first attribute of the usability evaluation, the five experts who participated also agreed that by using the e-LSO, they could specify their goals according to their requirements. The experts also agreed that they could select the evaluation criteria, sub-criteria provided by the e-LSO according to their requirements. However, in this evaluation, no additional criteria or sub- criteria were added by the experts. The experts also agreed that the evaluation criteria, sub-criteria and the e-LS alternatives provided were readily available in the e-LSO for evaluation purposes. The experts also agreed that the evaluation criteria and sub-criteria provided in e-LSO were suitable to be used for evaluating the e-LS. This agreement indicates that all the criteria which had been validated by the experts in this study could be used in the evaluation of the e-LS. The experts were also asked to indicate whether the proposed model provided comprehensive and adequate criteria for them to evaluate the e-LS. The experts indicated that they agreed that the e-LSO has provided them with comprehensive and adequate criteria for evaluating the e-LS. This shows that the criteria and sub-criteria provided in the e-LSO were comprehensive and adequate to be used as they support the needs of the experts who were from different organizations.

The experts also agreed that they could select and add the e-LS alternatives for evaluation, pointing out that it was easy to select the evaluation criteria, sub-criteria and the e-LS for evaluation. This shows that the e-LSO provided experts or users with the flexibility to specify a goal, select evaluation criteria, sub-criteria and e-LS alternative which have all been stored in the e-LSO database. Therefore, a customized decision model to evaluate the e-LS could be constructed by users, based on their needs. When queried about the technique used in the evaluation, the experts found that it was easy to use the pairwise comparison judgment process on the criteria, sub-criteria and the e-LS in the evaluation process.

Selecting the criteria, sub-criteria and the e-LS for evaluation were also hassle-free as all of these have been provided by the e-LSO. Experts noted that the scale provided for ranking the evaluation criteria, sub-criteria and e-LS alternatives have minimal uncertainty in making the judgment in the evaluation. They further agreed that the e-LSO could improve the speed of the evaluation process for the e-LS. Clearly, the experts also found the e-LSO to be useful for the evaluation and selection of the e-LS because by using the e-LSO, the experts found the guidelines and procedures easy to follow. In addition, the help support provided within the e-LSO enabled any mistakes made in the pairwise comparison judgment on the evaluation criteria, sub-criteria and the e-LS to be highlighted. Thus, any possible error, such as data entry errors, could be analyzed by looking at the consistency ratio result provided by the e-LSO.

The experts also observed that the results provided by the e-LSO could be understood easily. Clearly, the e-LSO provides an option for users to view the results either in text form or in a Graphical user interface (GUI). The detailed results showing the priority values for the evaluation criteria, sub-criteria and the e-LS were calculated and these could be viewed through the e-LSO. These outcomes give the experts a higher confidence for decision making in the final stages when the results are obtained. Nonetheless, the experts were not all agreeable with the pleasantness of the interface of the e-LSO although they noted that the e-LSO has all the expected functions and capabilities for e-LS evaluation. Overall, the experts agreed that they were satisfied with the e-LSO. Table 7.20 shows the items being evaluated and the mean average for each item obtained from the 5 experts in evaluating the usability of e-LSO.

Table 7.20: The Items Being Evaluated and the Mearn Average for Each Item

No	Attributes	Mean Average
1.	I can specify the evaluation goal according to my requirements	5.6
2.	I can select the evaluation criteria and sub-criteria according to my requirements	5.2
3.	I can add other evaluation criteria and sub-criteria according to my requirements	4.8
4.	The criteria, sub-criteria and e-Learning software alternatives for evaluation are readily provided in e-LSO	5.4
5.	The evaluation criteria and sub-criteria are suitable for e-Learning software evaluation	6
6.	The evaluation criteria and sub-criteria provided are comprehensive and adequate for e-Learning software evaluation	6.2
7.	I can select e-Learning software alternatives for evaluation	5
8.	I can add other e-Learning software alternatives for evaluation	4.4
9.	It is easy to do pairwise comparison and rank each criteria, sub-criteria and e-Learning software alternative with e-LSO	5.2
10.	It is easy to select the evaluation criteria, sub-criteria and e-Learning software for evaluation	4.8
11.	The scale provided to rank the evaluation criteria, sub-criteria and e-Learning software alternatives minimize uncertainty in my judgement	5
12.	I can quickly complete the evaluation process with e-LSO	4.6
13.	e-LSO is useful in the evaluation and selection of e-Learning software	5.4
14.	It was easy to learn to use e-LSO	4.6
15.	e-LSO show me mistakes that I have made in the pairwise comparison judgment on the criteria, sub-criteria and e-Learning software	4.8
16.	The evaluation result is easily understood	5.4
17.	I am confident with the result to assist me in the selection of e-Learning software	5.2
18	The interface is pleasant	4.2
19.	The interface is easy to navigate	4.2
20.	e-LSO has all the functions and capabilities I expect it to have	5.2
21.	Overall, I am satisfied with e-LSO	5.6

7.6 Evaluation of e-LSO's Limitation and Strength

Upon completion of the usability questionnaire, the experts were requested to answer several questions on why they specified the goals for evaluation. This is followed by the benefit, strengths and limitation of the e-LSO. Some suggestions were also provided to improve the e-LSO.

a. Goal for the Evaluation of e-LS

In the specification of the goals, the experts provided several variations. Expert E1 specified that the e-LS must meet user requirements and that it must be within the budgeted cost of the organization. Expert E2's goal was to search for a free e-LS that fulfilled the organization's requirements. Expert E3's goal was to search for an e-LS with a reasonable cost. Expert E4's goal was that the e-LS must meet the organization's needs. Expert E5's goal was to search for an e-LS that can function well. Clearly, all these goals vary from one expert to another.

b. Requirements for the Evaluation of e-LS

In order to realize the benefit of acquiring the e-LS, the experts were asked to determine the requirements in the evaluation of the e-LS. Expert E1 required an e-LS that functions, is usable and is at a reduced cost. Similar to E1, Expert E2 also required an e-LS that functions at a reduced cost. The e-LS that functions well could be maintained and is reliable and usable with good security features. Expert E3 required an e-learning that can function well, is usable and is cost effective. Expert E4 however, identified that the e-LS preferred should be cost-effective and should carry the suitability, flexibility and consistency features. Expert E5 was concerned with an e-LS that functions, ease of use, and preferred the e-LS that could be customized and learned easily.

c. The Evaluation Criteria and Sub-Criteria Chosen in the Evaluation of the e-LS

During the interview, the experts were also asked about their choice of evaluation criteria and sub-criteria. Expert E1 emphasised that the selected criteria and sub-criteria were important criteria needed by the government in the implementation of the e-LS. Expert E2 mentioned that the criteria and sub-criteria selected for the e-LS were required by the e-Learning development team. Expert E3 mentioned that the selected criteria and sub-criteria were relevant with the needs of the e-LS evaluation in his organization. According to E3, the *Functionality* and *Usability* criteria should be considered for any software evaluation requirement. Expert E4 noted that the selected criteria and sub-criteria were adequate to be considered as the most critical criteria in benchmarking the success of the e-LS usage and implementation. Expert E5 was concerned about the *Functionality*, *Usability* and *Reliability* criteria because these were important for selecting the correct e-LS to support his job functions. Thus, it seems obvious that the selection of criteria and sub-criteria varied from one expert to another based on their requirements and needs.

d. e-Learning Software

Expert E2 mentioned that as the e-LS will be implemented for the whole campus, their organization needs a software that can fulfill the important requirements and which can also serve all the users including the lecturers and students. Expert E3 pointed out that in the government procurement process, the cost is an important criterion, thus requiring an e-LS which could reduce the cost of the overall e-learning implementation is a better alternative. Expert E4 indicated that the current e-LSs that were selected for the evaluation process were highly recommended for his organization. Expert E5 nonetheless, selected the e-LS which had significant relations with the evaluation criteria and the chosen sub-criteria which also meets her organization's objectives.

e. Comparison of the Current Method With the e-LSO

The experts were also asked to compare the current method that is available for evaluating the e-LS with the e-LSO. In the case of Expert E1, interviews were conducted with users to identify the evaluation criteria. Vendors were also invited to provide the evaluation criteria and to suggest the e-LS. Expert E1 also refers to the ISO/IEC 9126-1 Quality Model to obtain information about the evaluation criteria. During internal meetings, the evaluation of the e-LS was conducted and the scoring method was used to weight the criteria and the e-LS products. Expert E1 mentioned that one the problems of the existing method is the lack of information and knowledge about the e-LS evaluation criteria. Expert E1 also highlighted that, in comparison, the e-LSO provided the information about the evaluation criteria and the sub-criteria, and this is certainly useful to his organization as the evaluation process can proceed smoothly. Expert E1 also added that the current method does not provide a support tool that can be used in the process of evaluating and selecting the e-LS in the current evaluation method. This makes the evaluation process a time consuming process since many processes are involved. Expert E1 also noted that in comparison, the e-LSO provides a list of criteria and sub criteria which enabled his organization to select them easily for the evaluation purposes. Expert E1 further mentioned that with the help provided by the e-LSO, he could learn and use the e-LSO for the evaluation process of the e-LS with much ease. Apart from this, Expert E1 also noted that the provision of the e-LSO had reduced the time of the evaluation process of the e-LS, compared to the current existing method.

Expert E2 noted that to determine the evaluation criteria of the e-LS, his organization needs to refer to the web sites or to do internet surfing. An internal meeting may also be conducted so as to brainstorm for the e-LS criteria and sub-criteria. His organization also relies on pamphlets, catalogues, articles and product documentations as a means to identify the evaluation criteria and the sub criteria of the e-LS. The current method for evaluating the e-LS seems to involve meetings, members of the technical staff and various other processes before a decision can be made about the e-LS evaluation process. According to E2, they also had to approach vendors who will be given the opportunity to propose their e-LS to his organization. Following this, the technical staff that participated in the internal meeting would then decide on the suitable e-LS offered by the vendors, based on the organization's needs. The decision on the selection of the e-LS would be finalised in the internal meeting.

In making a comparison between the current existing method in the evaluation of the e-LS with the e-LSO, Expert E2 specified that the e-LSO is a new way to evaluate the e-LS because it provides a software tool that assists in the evaluation process unlike the current existing method which does not offer a supporting tool. Further, Expert E2 was very excited with the flexibility offered by the e-LSO which allowed him to construct his own decision model in the evaluation process of the e-LS based on his organization's needs. However, it was added that, as a new approach for the evaluation of the e-LS, users need to understand the functionality of the e-LSO before it could be used efficiently.

To understand Expert E3's feedback about the comparison between the current existing method and the e-LSO, Expert E3 noted that his organization had to conduct interviews with the users in order to determine and establish the evaluation criteria that can be used for evaluating the e-LS. Expert E3 also scrutinizes information provided by vendors and he also refers to the ISO/IEC 9126-1 Quality Model to gather more input about the evaluation criteria. His organization tends to rely on internal meetings as well as review documentations, pamphlets and articles provided by software vendors. Expert

E3 also uses the Scoring method to evaluate the e-LS alternatives from the vendors. He clearly stated that the current existing method did not use any support tool as a specific technique for the e-LS evaluation. Expert E3 also noted that, in comparison, the e-LSO provides the much needed information in terms of the criteria and sub-criteria of the e-LS evaluation without the need to refer to vendors. This saves a lot of time. It was further mentioned that the e-LSO was more practical as it also provides a more effective tool in the evaluation process which enabled results of the criteria and sub-criteria to be compared. This makes decision-making more effective.

Meanwhile, Expert E4 mentioned that in order to determine and establish the e-LS evaluation criteria for his organization, information was extracted from the web sites through internet surfing, Internal meetings were also conducted to brainstorm for ideas and the information provided by the vendor in terms of articles, pamphlets and documentations would be considered. Reference would also be made to the ISO/IEC 9126-1 Quality Model. The scoring method is used in the evaluation phase. However, in comparison, it was noted that the e-LSO was easy to apply for making decisions about the selection of the e-LS. Expert E4 further stated that the current existing method consists of a complex task, involves to many staff and consumes too much time.

The last expert, E5 noted that, there were specific approaches in the current existing method which have been used by users to compare and evaluate the e-LS. However, in order to identify the evaluation criteria, E5 had to surf the vendor’s web site and review the e-LS products’ documentation that was provided by the vendor. The Benchmarking technique was used and users were invited to test several e-LS alternatives and then to decide which e-LS suits their needs. The decision about the selection of the e-LS was made in the meeting. As a comparison, Expert E5 commented that the e-LSO was useful in assisting his organization with the evaluation of a suitable e-LS for the users.

f. Strength of the e-LSO

Among the strengths noted, the e-LSO was described as an easy learning process. The experts commented that the availability of the help option, coupled with the error identification which highlighted mistakes made in the pairwise comparison judgment on the criteria, sub-criteria and e-LS, were great features of the e-LSO. The combined view of the results in the form of text and graphical interface, also assisted the comprehension of the results obtained. Furthermore, since the calculated values of the various criteria components are also shown, experts also acquire a level of added confidence when considering the accuracy of the results.

Expert E1 indicated that the current existing method relied on information obtained from the internet, which may take some time to source and filter. E1 also commended that the e-LSO readily provides these evaluation criteria and sub-criteria as well as the e-LS alternatives. E1 also mentioned that by using the e-LSO, experts would be able to select the evaluation criteria, sub- criteria and e-LS alternative to construct their own decision model.

Moreover, users may give weights to particular evaluation criteria, sub-criteria and the e-LS alternatives selected in the pairwise comparison judgment. The e-LSO can automatically calculate the results of the weight and present the results of the e-LS alternatives in the form of text and graphic figures. This ability to view the results is a value added component that can assist users in evaluating the criteria, sub-criteria and the e-LS alternatives.

Expert E2 stressed that the e-LSO was a new and innovative method for the evaluation and selection of the e-LS, adding that it is current and it hastens the decision making of decision makers as the results produced are tangible. Expert E2 also added that the current existing evaluation method was based on ad hoc meetings and the decision of selecting the e-LS would be made in the meeting session. In comparison, the e-LSO could provide a systematic approach which assist users in the evaluation of the e-LS.

Expert E3 noted that the e-LSO possessed a huge difference when compared to current existing methods because it offers a systematic approach for evaluating the e-LS through a sequence of steps. Expert E3 also remarked that the results calculated were easy to read and understand since the scores were provided in a graphical format.

Expert E4 commented that the e-LSO could display the score and the comparison analysis between software priorities visibly. This is helpful to decision maker as they can then correctly and confidently select the most suitable e-LS based on the results. Expert E4 added that the e-LSO is a good tool which could assist in the evaluation and selection process of the e-LS.

Expert E5 commented that the e-LSO provided support for the MCDM. It offers a systematic method to compare, evaluate and select based on a list of e-LS alternatives as well as a list of defined evaluation criteria and sub-criteria. Expert E5 was of the opinion that it is good to have a systematic software tool such as the e-LSO that can help decision makers to make fast decisions accurately based on their organization's needs.

f. Weakness of the e-LSO

In looking at the weakness of the e-LSO, Expert E1 commented that the interface was too rigid and did not make good use of colors. Expert E2 also remarked that a new user would need some time to study the system before the system can be used efficiently. It was observed that a new user may find it hard to understand and navigate the interface of the e-LSO. Experts E3 and E4 did not give any opinion about the weakness of the e-LSO although Expert E4 agreed with EI that the interface seemed to be too rigid. Expert E5 commented that the calculation time of the pairwise comparisons would significantly increase as more evaluation criteria, sub-criteria and e-LS alternatives are considered.

h. Future Improvement for the e-LSO

Several improvements can be made to the e-LSO. Expert E1 suggested that the Graphical User Interface (GUI) could be improved by using a better color scheme. Furthermore, the results should contain some explanations about the calculated values presented. A similar comment was made by E2, who recommended that the e-LSO provide some information about the results obtained from the calculation, and these can be presented more clearly for the users. Experts E3 and E4 did not give any opinion to this question although Expert E4 suggested a guidance such as a tutorial for beginners. Expert E5 recommended that additional visual results be presented instead of only one and these variations should be viewable as well as printable.

7.7 Summary

This chapter had discussed the results of the evaluation of the e-LSO. It reported the existing practices of the e-LS evaluation made by selected experts. The results include the application of the criteria in the ISQM and the actual utilization of the proposed framework when using the e-LSO tool for the e-LS evaluation. The results of the usability of the e-LSO also showed that the default criteria and the sub-criteria in the ISQM were found to be sufficient for the evaluation of the e-LS. The experts were satisfied with the performance of the e-LSO. They commented that the e-LSO which had consolidated the criteria from the ISQM by using the Fuzzy AHP technique as a tool to assist in the evaluation of e-LS was beneficial for users. The result of the usability evaluation revealed that, the e-LSO that was implemented into the ISQM-Fuzzy AHP evaluation framework could be used by organizations to facilitate the evaluation process of the e-LS.

CHAPTER 8: CONCLUSION

8.1 Introduction

The acquisition of the e-LS for e-Learning implementation in organizations requires a huge amount of financial investment. The wrong selection of the e-LS could cause organizations to lose a lot of money as a result of the investments made for the e-Learning implementation. In this regard, the evaluation of any e-LS that is to be used for any e-Learning implementation has to be considered with great care. Review from past studies has revealed that the evaluation of the e-LS has been considered to be a complex and difficult task because it involves many processes, it comprises many evaluation criteria and sub-criteria and there are many varieties of e-LS to be considered too. Furthermore, the evaluation process can differ from one individual to another and the processes involved may be dissimilar from one stage to another stage. Past studies have also shown that no standard guideline is available for use. The preliminary survey conducted of 50 experts also noted the gap. The results drawn from the preliminary survey had shown that organizations were facing difficulties in the evaluation process of the e-LS. Responses noted from the experts point to the lack of a specific guideline that can be used for the e-LS evaluation process currently in Malaysia. The gap noted in past studies and the inadequacy highlighted by the preliminary survey have motivated this study to consider the formulation of an e-LS evaluation framework that is not only current and update but will also reduce the problems faced by users of the e-LS.

The framework that is formulated in this study aims to fulfil the needs of the current users. The framework will consist of a sequence of processes and it uses the Fuzzy AHP technique to enable the e-LS evaluation for organizations. It is formulated based on the consolidation of the Integrated Software Quality Model (ISQM) which consists of relevant and important evaluation criteria and sub-criteria which have been obtained from literature and some additional criteria and sub-criteria which were obtained from the Delphi survey administered on 31 experts. The framework also includes a tool that was specifically developed to assist users in the evaluation process of the e-LS. It is proposed that organizations use the proposed e-LS evaluation framework and the tool provided as a guideline to support and assist them in the evaluation of a suitable e-LS.

This chapter consists of several sections. Section 8.1 highlights the introduction of this chapter. Section 8.2 reiterates the research objectives and research questions. Section 8.3 lists the contributions of the study. Section 8.4 acknowledges the limitations of the study. Section 8.5 highlights the recommendations for future study and Section 8.6 concludes the chapter.

8.2 Research Objectives and Research Questions

Four research objectives and research questions were introduced at the beginning of the study. The research objectives were:

i. To investigate the limitations of the current practices noted in the evaluation and selection of the e-LS.
ii. To formulate the ISQM-Fuzzy AHP evaluation framework for the e-LS evaluation.
iii. To develop a tool based on the ISQM-Fuzzy AHP evaluation framework by using evolutionary prototyping approaches.
iv. To evaluate the usability of the tool (e-LSO) in an e-LS evaluation by using the Post-Study System Usability Questionnaire (PSSUQ).

To realize the research objectives, the research questions were posed and they encompass:

i. What are the limitations of the current practices noted in the evaluation and selection of the e-LS?
ii. How is the ISQM-Fuzzy AHP evaluation framework formulated for the e-LS?
iii. Based on the ISQM-Fuzzy AHP evaluation framework, how is the tool developed for the e-LS evaluation by using evolutionary prototyping approaches?
iv. How is the usability of the tool (e-LSO) be evaluated for the e-LS evaluation by using the PSSUQ ?

This section presents the research findings with reference to the research objectives and research questions.

Research Objective 1: *To investigate the limitations of the current practices noted in the evaluation and selection of the e-LS*

Research objective 1 was addressed to investigate the limitations of the current practices noted in the evaluation and selection of the e-LS. Up until now, no study has been conducted to provide information about the current practices of the evaluation and selection of the e-LS, particularly in Malaysia. This has motivated the current study to be undertaken. The following research question relates to research objective 1:

Research Question 1: *What are the limitations of the current practices noted in the evaluation and selection of the e-LS?*

A preliminary survey was conducted to answer Research Question 1. The preliminary survey covered an investigation on the issues of the implementation of e-Learning, the stages and methods in the evaluation and selection process of the e-LS, the evaluation criteria, the tools used for evaluation and the problems encountered in the evaluation and selection process. The method in undertaking the preliminary survey has been described in Chapter 3. The results have been presented in Chapter 4. The preliminary survey has identified eight general processes in the evaluation of the software. In the case of the e-LS evaluation, it was interesting to note that organizations did not strictly adhere to all the stages when evaluating the e-LS. The evaluation processes among organizations vary. It appears that organizations tend to select only portions of the stages involved in the general software evaluation process while evaluating their e-LS. This may be due to the complexity and difficulties of the evaluation task which involves several processes which can be complex and time consuming besides involving high operation costs. With the many processes involved in the evaluation of the e-LS, a standardized guideline is necessary. However, as was highlighted by the preliminary survey, currently there is no standardized guideline and this makes the evaluation process a tough one for the many organizations implementing the e-Learning platform.

It was also interesting to point out that some experts also have a lack information and knowledge about the e-LS evaluation criteria. This is another significant problem faced by organizations and experts when in the process of evaluating and selecting the e-LS for the e-Learning implementation. The existing ISO/IEC 9126-1 Quality Model consists of a general criteria for users to follow when evaluating the various e-LS products. Due to its general characteristics, it appears that the evaluation criteria offered by the ISO/IEC 9126-1 Quality Model is not adequate enough to meet the needs of specific software products such as the e-LS. In particular, the results drawn from the preliminary survey had shown the unavailability of a standard model that also consists of important e-LS evaluation criteria that can be beneficial to users implementing the e-Learning platform. It appears that most organizations in Malaysia tend to rely on the various unreliable approaches and biased sources to determine their evaluation criteria when expected to evaluate the e-LS product. These approaches can be traced to the web sites and Internet, pamphlets and brochures from vendors and decisions made by a group of technical experts or some internal staff during a meeting. All these input provided by the experts suggest that there is a need to construct a specific quality model for the evaluation of the e-LS and this model should consists of sufficient and important e-LS evaluation criteria. In relation to the support tool required in the evaluation process, the preliminary results also highlighted that there is a lack of supporting tools for use in the evaluation process of the e-LS.

Research Objective 2: *To formulate the ISQM-Fuzzy AHP evaluation framework for the e-LS evaluation*

As mentioned earlier in research question 1, the general evaluation process of a software can be complex and difficult to be carried out in the e-LS evaluation. The stages are time consuming and costly. Furthermore, existing study also showed that there is no standard evaluation framework that comprise an adequate evaluation process, adequate evaluation criteria and which uses an adequate evaluation technique as a guideline for organizations to follow as a support in the evaluation of the e-LS.

Therefore, the research objective 2 was posed with the aim of constructing an Integrated Software Quality Model (ISQM) and to formulate the ISQM-Fuzzy AHP evaluation framework for e-LS evaluation. To fulfil research objective 2, the research question 2 was asked.

Research Question 2: *How is the ISQM-Fuzzy AHP evaluation framework formulated for the e-LS?*

Prior to the formulation of the ISQM-Fuzzy AHP framework, an integrated software quality model (ISQM) was constructed. For the construction of the ISQM two tasks were involved.

Firstly, a thorough literature review was carried out to identify the relevant evaluation criteria. This was followed by two rounds of the Delphi survey which involved experts to validate the identified e-LS evaluation criteria and the sub-criteria. Both tasks have been explained in Chapter 3. The results have been reported in Chapter 5. From the literature review, 11 evaluation criteria and 66 sub-criteria relevant for the e-LS evaluation were collected. From the two rounds of the Delphi Survey, 16 additional sub-criteria, which were not reported by any literatures, were added by the experts. One sub-criterion was rejected due to its low consensus among experts. The 11 evaluation criteria and the 81 sub-criteria were used to construct the ISQM. The construction of the ISQM was discussed in Section 5.4. It consists of the relevant and important evaluation criteria and sub-criteria for the e-LS evaluation. These were all identified from the literature review and the Delphi survey. The ISQM model is shown in Figure 8.1.

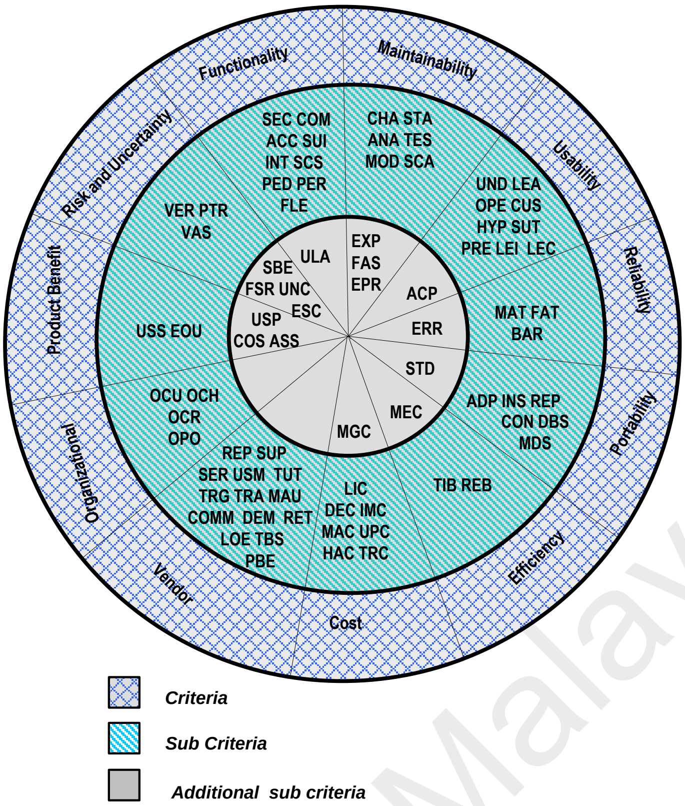


Figure 8.1: ISQM for e-LS Evaluation

Similar to the ISO/IEC 9126-1 Quality Model, the ISQM also consists of the evaluation criteria and the sub-criteria which are then decomposed into a hierarchical structure for the e-LS evaluation. The representation of the Hierarchical Structure for the e-LS evaluation criteria and sub-criteria of the ISQM is illustrated in Figure 8.2.

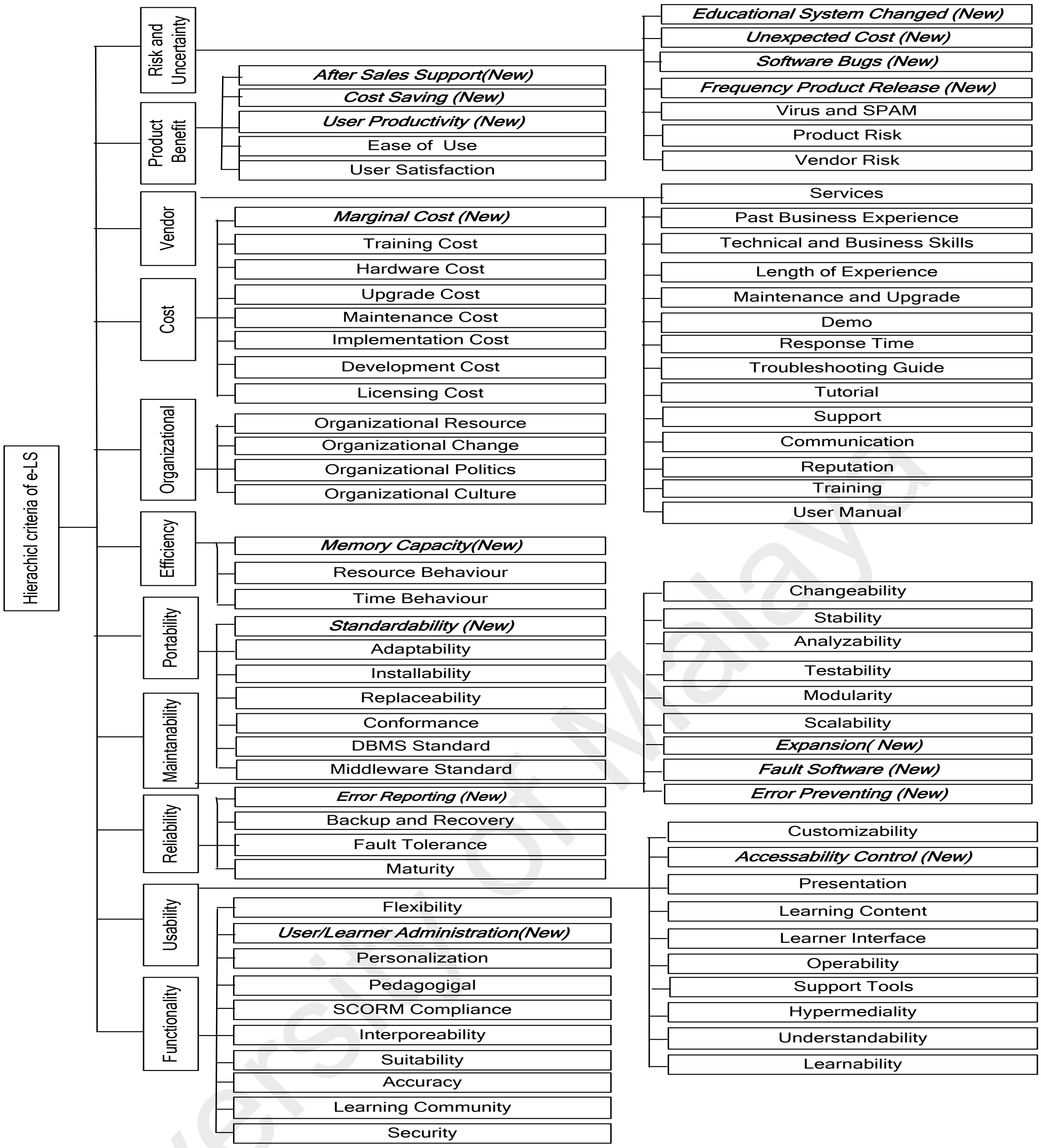


Figure 8.2: Hierarchical Structure for the e-LS Evaluation Criteria and Sub-Criteria of the ISQM

Secondly, the framework for the e-LS evaluation incorporates the ISQM and the Fuzzy AHP technique. The processes involved in the ISQM-Fuzzy AHP framework provide a guideline for organizations to follow when evaluating the respective e-LS. The ISQM-Fuzzy AHP framework is shown in Figure 8.3.

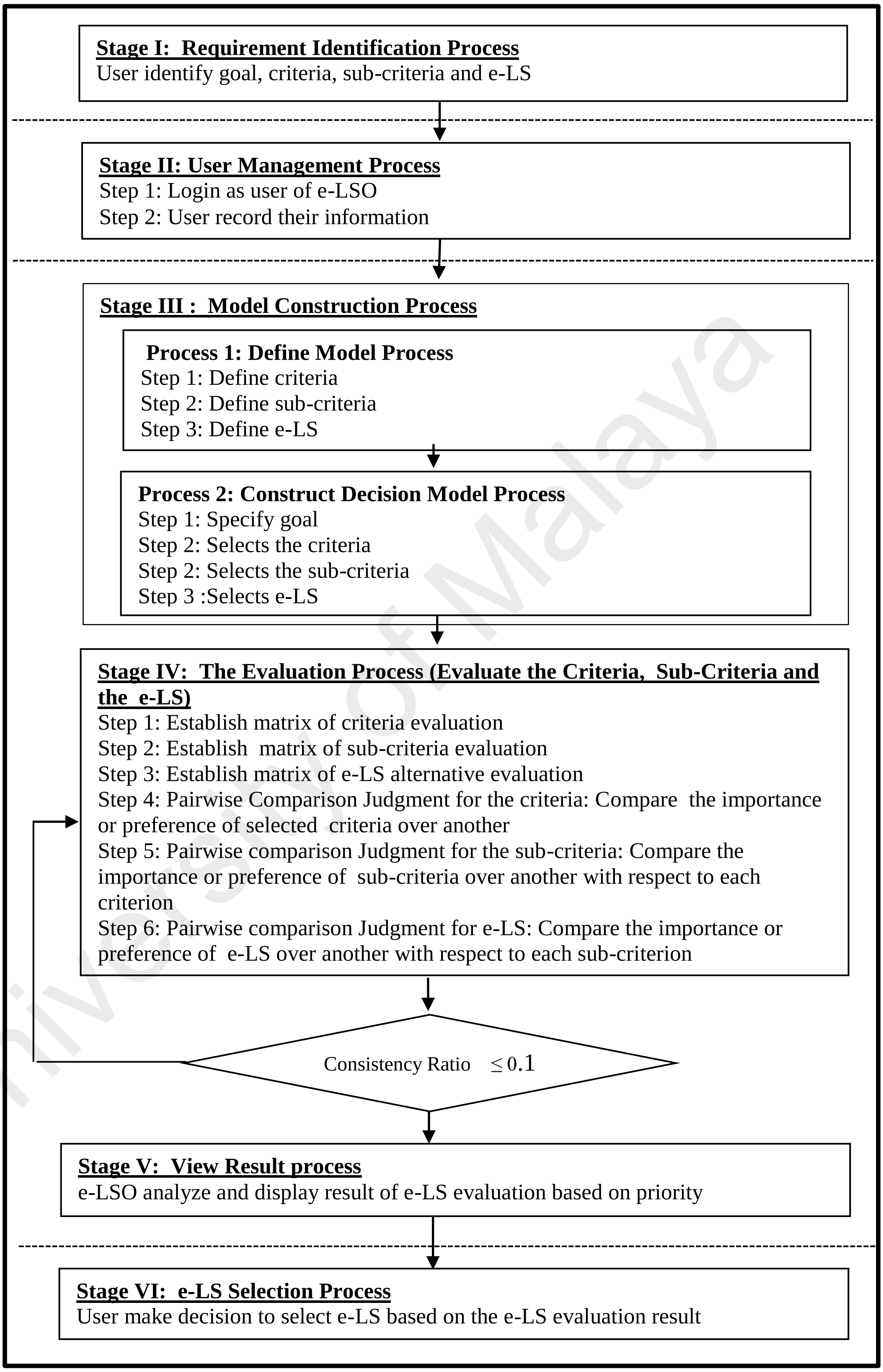


Figure 8.3: The ISQM-Fuzzy AHP Evaluation Framework for e-LS Evaluation

The ISQM-Fuzzy AHP evaluation framework for the e-LS evaluation has been adapted based on stages in the COTS based process. The Fuzzy AHP technique was applied as an alternative for the traditional AHP technique in the existing COTS based process. The steps involved in the Fuzzy AHP technique were refined and then automated in the e-LSO tool that was developed. All information regarding the criteria and the sub-criteria of the ISQM are stored in the e-LSO database. This forms the e-LS evaluation framework for the e-LS evaluation. The ISQM-Fuzzy AHP framework will consist of a sequence of processes and these are divided into six stages encompassing: Sage I: Requirement identification process; Stage II: User Management Process; Stage III: Model Construction Process; Stage IV: Evaluation Process; Stage V: View Result Process; and Stage VI: Decision Making for selecting the e-LS Process. These processes have been discussed in Section 5.5. In the ISQM-Fuzzy AHP framework, the e-LSO will be used in Stage II, Stage III, Stage IV and Stage V to assist in the evaluation phase.

Research Objective 3: *To develop a tool (e-LSO) based on the ISQM-Fuzzy AHP evaluation framework using evolutionary prototyping approach*

Research objective 3 was identified as a means to develop a tool that is based on the ISQM-Fuzzy AHP evaluation framework and which can support the evaluation of the e-LS. Results obtained from the experts in the preliminary survey have strongly indicated the need for a tool to assist organizations in the evaluation of the e-LS. In this regard, the ISQM-Fuzzy AHP evaluation framework would require organizations to use a tool (e-LSO) in the evaluation process of the e-LS. The e-LSO developed in this study would assist organizations in defining and constructing their own decision model based on their needs of the e-LS evaluation. Besides, the e-LSO also facilitates the complexity of the evaluation process by using the Fuzzy AHP technique which can provide all the relevant and important evaluation criteria, sub-criteria in the ISQM for users. It also makes the e-LS alternatives available for organizations when conducting the evaluation process. Furthermore, since organizations may add additional e-LS products into the database, the wide choices allow them to construct their own decision model based on their needs and goals. To develop this tool, the following research question was posed:

Research Question 3: *Based on the ISQM-Fuzzy AHP framework, how is the tool developed for the e-LS evaluation by using evolutionary prototyping approaches?*

The e-LSO was developed to answer research question 3. An evolutionary prototyping approach was selected in order to develop the e-LSO. To accomplish this, five steps using the evolutionary prototyping approach was applied. This was explained in section 3.4.3. The development of the e-LSO has been discussed in Chapter 6.

Research Objective 4: *To evaluate the usability of the tool in e-LS evaluation using PSSUQ*

Research objective 4 was addressed so as to evaluate the usability of the e-LSO. The usability evaluation was conducted to answer the research question 4:

Research Question 4: *How is the usability of the tool be evaluated for the e-LS evaluation by using the PSSUQ?*

The result of the usability of the e-LSO has been reported in Chapter 7. Five experts were invited to test the tool in the usability evaluation of the e-LSO. These experts were newly selected and were not involved in the preliminary survey nor the Delphi survey. The usability evaluation procedure of the e-LSO has been discussed in section 3.5.3. Prior to using the e-LSO, the five experts were required to provide information about their existing evaluation practices. These were discussed in section 7.2. The experts were trained individually in their work place on how to use the e-LSO for the e-LS evaluation. Next, they were required to use the e-LSO to construct their own decision model based on their needs. This process involved the users in defining their goal, selecting the criteria, selecting the sub-criteria and selecting the e-LS alternatives. The source of the criteria and sub-criteria and the e-LS were from the ISQM and stored in the e-LSO. The criteria, sub-criteria and e-LS selected by each expert have been discussed in Chapter 7. The list of the criteria, sub-criteria and the e-LS used for the evaluation process is attached in Appendix K. With the e-LSO, the evaluation of the criteria, sub-criteria and the e-LS alternatives were conducted by using a pair wise comparison, as suggested in the Fuzzy AHP technique. The evaluation results of the e-LS could be viewed by the experts using the e-LSO. The PSSUQ questionnaire was given to the experts to obtain their feedback about the usability of the e-LSO. The results taken from the usability evaluation showed that experts agreed that they can use the criteria, sub-criteria and the e-LS provided in the e-LSO for the evaluation process. This shows that the criteria, sub-criteria and the e-LS validated by the experts could be used in the evaluation of an e-LS.

In the evaluation of the e-LS, the Fuzzy AHP technique was applied in the e-LSO. Thus, the experts revealed that the e-LSO provides flexibility for them to select those criteria, sub-criteria and e-LS alternatives to construct their own decision model based on their needs. The usability evaluation of the e-LSO also showed that the experts in this study have agreed that the Fuzzy AHP technique could be used as an alternative for the traditional AHP technique when evaluating the e-LS. They also agreed that the scale provided for ranking the evaluation criteria, sub-criteria and the e-LS alternatives minimizes uncertainties when making judgments in the evaluation process. The overall results also showed that all the five experts being surveyed and interviewed were satisfied with the usability of the e-LSO for their own e-LS evaluation processes.

The result of the usability evaluation of the e-LSO has been discussed in section 7.5. Following the report of the usability of the e-LSO, the experts were also requested to provide their opinions about the strengths and weaknesses of the e-LSO as well as some recommendation for future improvement of the e-LSO. These results have been discussed in section 7.6. From the findings of this study, it can be concluded that all of the research questions have been answered and the research objectives have been achieved successfully.

8.3 Contribution of Study

This study has contributed to the development of a comprehensive framework that can serve as a guideline for organizations to follow when evaluating the e-LS based on their needs of e-Learning implementation. This can be used according to their respective needs and goals. In particular, the contributions of this study include:

i. The first study of the e-LS evaluation done in Malaysia and a study which revealed what the current practices of the e-LS evaluation and selection are.

ii. The construction of an ISQM which can be applied for the e-LS evaluation by organizations; it also consolidates a list of important evaluation criteria and sub-criteria which have been validated by experts comprising Technical Experts, Decision Makers and Academicians/Researchers.

iii. The formulation of an e-LS evaluation framework that contains a sequence of processes which integrates the ISQM and the Fuzzy AHP technique as a guideline for organizations to support in the evaluation of their e-LS.

iv. The development of the e-LSO as a usable tool which consolidates the Fuzzy AHP technique used in the proposed framework as a means to assist organizations in the evaluation of the e-LS.

8.4 Limitations of Study

The limitations of the study were identified as follows:

i. The preliminary survey for collecting information was conducted only in Malaysia, which may be influenced by the local conditions of the country.

ii. The pairwise comparison judgments noted in the evaluation process takes times if the number of criteria and the sub-criteria increases.

iii. The e-LSO does not provide a list of user requirements in the evaluation of the e-LS. This implies that the organizations can select their own criteria, sub-criteria and the e-LS alternatives when considering the e-LS evaluation process. However, the user needs to define his/her goals in advance of the requirements before using the e-LSO.

8.5 Future Study

The following recommendations are proposed for future studies focusing on the same topic. They include:

i. Experts' opinion should be sourced from other regions of the world such as from other Asian and European countries so as to give the study a more global view of the e-LS evaluation requirements.

ii. The Fuzzy AHP technique could be extended to other MCDM methods such as Technique for Order of Preference made by the Similarity to Ideal Solution (TOPSIS) to reduce pair wise comparison.

iii. In the current study, the organizations were assumed to have their own requirements in the evaluation of the e-LS. Future studies may want to consider a list of requirements that organizations can select and these can be stored in the e-LSO tool for the e-LS evaluation made by organizations.

iv. More e-LS could be considered for future studies so as to provide more options for users to select from.

8.6 Conclusions

This study has been directed towards formulating a framework for the e-LS evaluation process, namely the ISQM-Fuzzy AHP. The study begins by investigating the limitations of the current practices noted in the evaluation and selection process of the e-LS in the Malaysian context. The ISQM was subsequently developed and it consists of a list of important criteria and sub-criteria which can be used for the e-LS evaluation process by organizations. The e-LS evaluation framework called the ISQM-Fuzzy AHP was proposed comprising a sequence of processes to support the evaluation of the e-LS. The ISQM-Fuzzy AHP evaluation framework also serves as a guideline to support organizations when required to evaluate the e-LS product during the e-Learning implementation. The proposed framework was used in the e-LSO to assist in the evaluation of the e-LS. The usability evaluation of the e-LSO was assessed by five selected experts. It was noted that the e-LSO was useful for organizations to evaluate the e-LS. The proposed e-LSO facilitates the complex task of evaluating the e-LS and it involves several processes; it provides a list of criteria, sub-criteria and the e-LS alternatives for organizations to select when evaluating the e-LS product. This e-LSO can also assist organizations to be more systematic, to reduce time and to cut down costs. Moreover, through the e-LSO, organizations could also construct their own decision model easily by selecting the available criteria, sub-criteria and e-LS provided in the database of the e-LSO. Based on this, it can be concluded that, the formulation of the ISQM-Fuzzy AHP evaluation framework and the construction of the e-LSO as a support in this study can effectively support and assist organizations in the evaluation of a suitable e-LS for e-Learning implementation, based on their needs.

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