ABSTRACT

Learning Management System (LMS) has now become a top priority and fundamental projects in organizations and educational institutions. There are both commercial and open source versions available for users, and they can be accessed over the Internet everywhere and any time. Selecting one LMS from these multiple options will be a serious challenge because each LMS alternative has its individual features. Several Multi-Criteria Decision Making techniques have been applied in various studies for solving different decision problems. Some of these techniques have also been applied for LMS evaluation; but there is a missing gap in using the fuzzy DEMATEL-TOPSIS integrated technique for LMS evaluation. Moreover, manual evaluation requires much time and effort, and errors or mistakes can easily be made. The evaluator also needs to have technical knowledge of the evaluation technique he/she will use. This shows that there is a need for a tool which will help, simplify and make an efficient LMS evaluations. In this thesis, a web-based LMS evaluation system is developed with Asp.net using the fuzzy DEMATEL-TOPSIS integrated technique. 24 most commonly used evaluation criteria are included in the system, also the top 10 open source LMS are included in the system. In the case study performed on Moodle, Sakai, Edmodo and ATutor based on accessibility, efficiency, flexibility, security and usability features. The result shows that Moodle LMS is the most suitable option based on the given requirements. This developed system will be beneficial to universities and organizations in choosing the right LMS that will suit their various needs. It will also serve as a guide for developers whom wish to develop an evaluation system.

Keywords: Learning Management System; LMS; evaluation; fuzzy logic; DEMATEL; TOPSIS; MCDM

ÖZET

Öğrenme Yönetim Sistemleri (ÖYS) kurumlarda ve eğitim ensititülerinde öncelikte olup temel proje haline gelmiştirler. Kullanıcılar için ticari ve ayni zamanda açık kaynak kodlu versiyonları mevcuttur ve bunlara herhangi bir zamanda ve herhangi bir yerde Internet üzerinden ulaşılabilmektedir. Her ÖYS'nin kendine has özellikleri olduğu için seçimi ciddi ve zor bir işlemdir. Seçenekler arasından ihtiyaçlara en uygun olanı seçebilme problemini çözmek için çeşitli uygulamalarda Çoklu Kriter Karar Verme teknikleri kullanılmıştır. Bu tekniklerin bazıları ÖYS'lerinin değerlendirmesinde de kullanılmıştır. Ancak alanyazın incelenmesinde ÖYS değerlendirmesi için bulanık mantık ile DEMATEL-TOPSIS tekniklerinin entegre edilerek kullanımında yeterli çalışmanın olmadığı belirlenmiştir. Buna ilave olarak, elle yapılacak olan değerlendirmeler ise zaman kaybına sebep olmakta ve ayni zamanda kolaylıkla hata yapılabilmektedir. Ayrıca değerlendirme yapan kişinin, değerlendirme yöntemi hakkında teknik bilgisinin olması gerekmektedir. Bu durum, verimli ÖYS değerlendirmesi yapabilmek ve değerlendirmeyi kolaylaştırmak için bir araca ihtiyaç olduğunu göstermektedir. Bu tezde, ASP.net ile bulanık mantıkla DEMATEL-TOPSIS tekniklerini entegre olarak kullanan ağ tabanlı ÖYS değerlendirme sistemi geliştirilmiştir. Alanyazından edinilen bilgiye dayalı olarak en yaygın kullanılan 24 tane değerlendirme kriterleri ile 10 tane açık kaynak kodlu ÖYS geliştirilen sistemde kullanılmıştır. Örnek çalışmada ise Moodle, Sakai, Edmodo ve ATutor ÖYS'leri tercih edilip erişilebilirlik, verimlilik, güvenlik ve kullanılabilirlik özellikleri seçilmiştir. Değerlendirme sonucunda Moodle ÖYS'nin belirlenen gereksinimleri karşılayacak en uygun ÖYS olduğu tesbit edilmiştir. Geliştirilmiş olan bu sistem, üniversitelerin ve kurumların gereksinimlerine ve ihtiyaçlarına göre doğru ÖYS seçimi yapmalarına yardımcı olacaktır. Ayni zamanda bu sistem, ÖYS değerlendirmesi üzerine çalışmak isteyen sistem geliştiricilere de kılavuz olacağı ümit edilmektedir.

Anahtar Kelimeler: Öğrenme Yönetim Sistemi; ÖYS, değerlendirme; bulanık mantık; DEMATEL; TOPSIS; MCDM

MUHAMMAD NAZIR MUHAMMAD

LEARNING MANAGEMENT SYSTEMS EVALUATION USING FUZZY DEMATEL-TOPSIS METHOD

NEU 2018

LEARNING MANAGEMENT SYSTEMS EVALUATION USING FUZZY DEMATEL-TOPSIS: A WEB BASED SYTEM

A THESIS SUBMITTED TO THE GRADUATE SCHOOL OF APPLIED SCIENCES OF NEAR EAST UNIVERSITY

By
MUHAMMAD NAZIR MUHAMMAD

In Partial Fulfilment of the Requirements for the Degree of Master of Science in Computer Information Systems

NICOSIA, 2018

LEARNING MANAGEMENT SYSTEMS EVALUATION USING FUZZY DEMATEL-TOPSIS: A WEB BASED SYTEM

A THESIS SUBMITTED TO THE GRADUATE SCHOOL OF APPLIED SCIENCES OF NEAR EAST UNIVERSITY

By
MUHAMMAD NAZIR MUHAMMAD

In Partial Fulfilment of the Requirements for the Degree of Master of Science in Computer Information Systems

NICOSIA, 2018

Approval Page

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Name, Last name:
Signature:
Date:

To my family...

ACKNOWLEGMENTS

First and foremost, I would want to express my earnest appreciation and thanks to my humble supervisor Prof. Dr. Nadire Cavus for her untiring support, advice and corrections, as well as guidance and for providing me with all the required skills and research tools to complete my thesis within the stipulated time.

In addition, my gratitude goes to the Department of Computer Information System, Near East University especially Prof. Dr. Dogan Ibrahim and Assist. Prof. Dr. Seren Basaran for helping me through my academic journey.

I also thank the jury members for their comments, suggestions and corrections that increase the quality of this thesis.

I will like to express my gratitude to my parents Assoc. Prof. Muhammad Babangida Muhammad and Safiyya Hussain Falaki who brought me into this world and for laying foundation for moral and educational discipline, also help and encourage me throughout my life.

I also thank my uncle Mustapha Hussain Falaki, his guidance, support and encouragement at various stages of my life have been of immense benefit to me.

Thank you.

ABSTRACT

Learning Management System (LMS) has now become a top priority and fundamental projects in organizations and educational institutions. There are both commercial and open source versions available for users, and they can be accessed over the Internet everywhere and any time. Selecting one LMS from these multiple options will be a serious challenge because each LMS alternative has its individual features. Several Multi-Criteria Decision Making (MCDM) techniques have been applied in various studies for solving different decision problems. Some of these techniques have also been applied for LMS evaluation; but there is a missing gap in using the fuzzy DEMATEL-TOPSIS integrated technique for LMS evaluation. Moreover, manual evaluation requires much time and effort, and errors or mistakes can easily be made. The evaluator also needs to have technical knowledge of the evaluation technique he/she will use. This shows that there is a need for a tool which will help, simplify and make an efficient LMS evaluations. In this thesis, a web-based LMS evaluation system is developed with Asp.net using the fuzzy DEMATEL-TOPSIS integrated technique. 24 most commonly used evaluation criteria are included in the system, also the top 10 open source LMS are included in the system. In the case study performed on Moodle, Sakai, Edmodo and ATutor based on accessibility, efficiency, flexibility, security and usability features. The result shows that Moodle LMS is the most suitable option based on the given requirements. This developed system will be beneficial to universities and organizations in choosing the right LMS that will suit their various needs. It will also serve as a guide for developers whom wish to develop an evaluation system.

Keywords: Learning Management System; LMS; evaluation; fuzzy logic; DEMATEL; TOPSIS; MCDM

ÖZET

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AHP:	Analytic Hierarchy Process
ANP:	Analytic Network Process
BNP:	Best Non-fuzzy Performance
CASE:	Computer Aided Software Engineering
CLI:	Command-Line Interface
DEMATEL:	Decision-Making Trial and Evaluation Laboratory
ELECTRE:	Elimination and Choice Expressing Reality
FAHP:	Fuzzy Analytic Hierarchy Process
FANP:	Fuzzy Analytic Network Process
FDEMATEL:	Fuzzy Decision-Making Trial and Evaluation Laboratory
FNIS:	Fuzzy Negative Ideal Solution
FPIS:	Fuzzy Positive Ideal Solution
FTOPSIS:	Fuzzy Technique for Order of Preference by Similarity to Ideal Solution.
GPL:	General Public License
ICT:	Information and Communication Technology
IDE:	Integrated Development Environment
ISO:	International Organization for Standardization
LMS:	Learning Management System
MCDM:	Multi Criteria Decision Making
NIS:	Negative Ideal Solution
OSS:	Open Source Software
PIS:	Positive Ideal Solution
PROMETHEE:	Preference Ranking Organization Method for Enrichment Evaluations
SCORM:	Sharable Content Object Reference Model

SDLC:	Software Development Life Cycle
TFN:	Triangular Fuzzy Number
TOPSIS:	Technique for Order of Preference by Similarity to Ideal Solution
UML:	Unified Modelling Language

CHAPTER 1

INTRODUCTION

This chapter gives the overall introduction to the selection and choosing the right learning management system, the problem, the aim of the study, the importance of the study, and the limitations as well as the overall overview.

1.1 Background

Nowadays, due to the advancements in information technologies and the development of the World Wide Web, educational institutions, organizations, research centers, government parastatals, and even the individuals have adopted the use of the Internet in their daily activities (Natarajan, 2015). Learning procedure has also been affected by the lively growth in the Information and Communication Technology (ICT) and the Internet area, which bring about the formation of new learning environments (Albarrak, Aboalsamh, and Abouzahra, 2010). The modern and affordable technologies inspired many educational institutions to have a different of alternatives to normal classroom instruction. Also, the advancements in the Internet technologies pave the way for the creation of new educational system named electronic learning (e-learning), where education and knowledge are being delivered to students via the Internet or related web technologies with a good standard and without any limitation to a particular location. It involves using multimedia which includes audio, video, animations and text graphics. The most widely form of e-learning is through a software application called learning management system (LMS) as outlined by (Cavus, 2013). The basic structure of LMS is shown in Figure 1.1. Also, the implementation of LMS needs huge amounts of money and commitment from the institutions and organizations (Edrees, 2013).

A LMS is defined as a software tool which manages, record, track, reporting as well as conveyance of education courses and trainings, which provides a means to easily trace and enrol in a relevant learning activity to acquire further skills (Ramesh and Ramanathan,

2013). In other words, Caminero et al. (2013) described LMS as a software system which comprises of different tools that support learning and teaching activities.

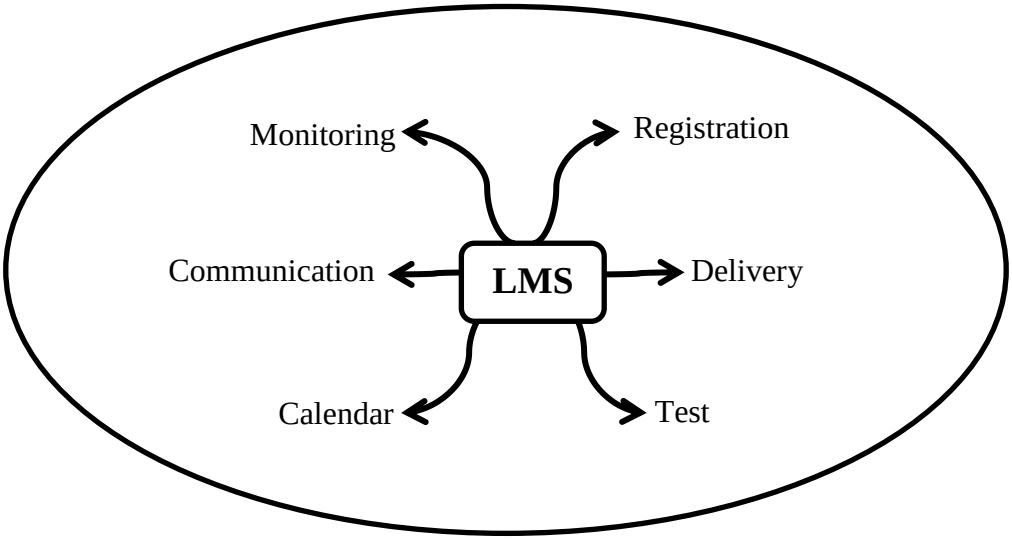

Figure 1.1: The components of LMS (Cavus, 2011)

Application of LMS is nowadays an essential pillar that supports and promotes educational systems, the rapid growth of computer and Internet-based technologies produces a substantial amount of LMSs available over the Internet, both the licensed and the free versions (Cavus, 2007). In the past years, educational institutions invested huge money and spend significant amounts of time in implementing LMSs (Edrees, 2013). But recently, users do prefer the open source versions because it is absolutely free, and most of the features required are available in the open source (Muhammad and Cavus, 2017a) Yet, there is a dilemma that users always found themselves in when they want to choose an LMS because of the different softwares available and each software has its own different specifications. This is an issue that will easily be tacked using a Multi Criteria Decision-Making (MCDM) methods because it involves multiple criteria to be examined and analysed before making selections.

Different decision-making approaches like Analytic Hierarchy Process (AHP) (Cetin, Isik, and Guler, 2010; Srdevic et al., 2012), Analytic Network Process (ANP) (Ergu et al., 2014), Fuzzy Analytic Hierarchy Process (FAHP) (Isik, Ince and Yigit, 2015), Smart algorithm (Cavus and Momani 2009), Fuzzy Elimination and Choice Expressing Reality (F-ELECTRE) (Rouyendegh and Erkan, 2013; Debnath, Majumder and Pal, 2016),

Preference Ranking Organization Method for (PROMETHEE) (Oh et al., 2015; Sen et al., 2015) and Decision-Making Trial and Evaluation Laboratory **(**DEMATEL) (Sumrit et al., 2013) have been used by many researchers to provide a solution for different decisions and evaluation problems, different methods are nowadays combined to enhance the evaluation process and give a more accurate result as stated by (Vinodh et al., 2016).

DEMATEL is a MCDM procedure used to identify the impact relationship map between evaluation criteria, the influence level of each criterion over the other, and then distribute the criteria into cause and effect groups (Kashi, 2015). It takes experts opinion as the degree of influence of each criterion on each other as its input, the result of the method is a diagram which shows the relationship between the affected criteria and the one that affected it. FDEMATEL is an expansion of DEMATEL which uses fuzzy values to represent crisp values. Decision problems are more accurate when fuzzy logic is used in its solutions because it overcomes the problem of unreliability and uncertainty of data (Chang, Chang and Wu, 2011).

TOPSIS is a technique used to measure the comparative value of each alternative, and also resolve decision problems using its powerful computational performance. The main concept of the technique is that it assumes that a preferred choice will get the least range from the positive ideal solution (PIS) and the highest from the negative ideal solution (NIS) (Shih et al., 2007).

Combination of DEMATEL and TOPSIS have also been applied in various researches to solve different MCDM problems (Dalalah, 2009; Chang, 2014; Sangaiah, Subramaniam and Zheng, 2015), also there are several researchers that make use of this integrated approach in a fuzzy logic environment, which deals with uncertainty in human thinking and yield a better result (Tseng, 2011; Dalalah, Hayajneh and Batieha, 2011; Visalakshmi and Lakshmi, 2015; Baykasoglu and Golcuk, 2017).

1.2 Problem

LMSs have become one of the key pillars of educational development. It is a multibillion-dollar market business which has a market share of $2.5 billion in the year 2016 and is presumed to rise by 23.1% between 2017 and 2018 (Docebo, 2014). Another report by

(Learning, 2017) forecasted that by 2023, the LMS market can reach $240B. Advancements in computer and web technologies bring about the high number of LMSs available online today. This makes it difficult for a user to select the most suitable one out of the large population (Cavus and Momani 2009). This brought about a multi-criteria problem that can be resolved using a multi-criteria decision-making approach MCDM. Many LMSs are available on the Internet in the free and licenced versions (Rafi, Samsudin and Hanafi, 2015), but most users prefer to use the open-source (Abdullateef et al., 2016) because it is free and it has almost all the features that are available in the commercial versions, but there is a great challenge that arises when a user wants to select an LMS that will suit his requirement due to the difference in specifications of different LMSs. Many researchers have proposed different methods to evaluate LMS based on different sets of criteria, but there is a missing gap in the fuzzy DEMATEL-TOPSIS integrated approach. Vinodh (2016) outlined that an effective solution cannot be achieved using a single MCDM technique especially in a very difficult multi-criteria decision problem. Another problem is that the manual evaluation method needs technical knowledge, sufficient time and effort. This means that there is a need for a system or a tool or engine that will simplify and ease the LMS evaluation that will make the right selection which will meet most if not all of the user needs (Cavus and Momani, 2009). Therefore, this thesis focuses on using an integrated MCDM approach with fuzzy logic values to evaluate Open Source LMS that will help users make a right LMS selection.

1.3 The Aim of the Study

The aim of this thesis is to develop a web-based system to evaluate and select the best LMS option out of different alternatives, the selection is based on set of selected criteria using an integrated fuzzy DEMATEL-TOPSIS technique.

1.4 Significance of the Study

The developed system will make LMS evaluation easier, faster and cost effective, it will also minimise human error and can be accessed from anywhere at any time. It will help educational institutions, organisations and individual LMS users in selecting the most appropriate and efficient LMS out of different options based on their individual requirements within short time. The study can also serve the future researchers in their

reference for making related research in the field of LMS evaluation, which can provide an idea to them that can make their work much easier.

1.5 The Limitations of the Study

Though this thesis will achieve its aim, there are some limitations caused by limited time and logistics:

- The study is limited from September, 2017 to January, 2018.
- The study uses the top 10 Open Source LMS: Moodle, Sakai, dotLRN, Claroline, ATutor, Ilias, Canvas, Edmodo, Dokeous and Olat.
- It is not possible to include all the LMS evaluation criteria, therefore, this study included 24 most common criteria as listed in Section 3.4.4
- The study is limited to only DEMATEL and TOPSIS technique with fuzzy values

1.6 Overview of the Study

The thesis comprises of 6 chapters in all:

Chapter 1 gives the overall introduction to the selection and choosing the right learning management system, the problem, the aim of the study, the importance of the study, the limitations as well as the overall overview.

Chapter 2 is the related research on LMS evaluation by different researchers, where different studies previously published in this subject area of the research was analysed, examined their findings and also study their missing gaps.

Chapter 3 is the theoretical framework of the study, discusses and give detailed explanations on web application, fuzzy logic, MCDM, DEMATEL and TOPSIS in one side, and on the other side it give a detail explanations on LMS, its types, its features and the alternatives used in the research.

Chapter 4 gives the detail description of the applications and tools used in the web based LMS evaluation system development. It also shows the developed system architecture and UML diagrams, which gives a visual representation of the design of the developed system.

Chapter 5 is the system implementation; a case study of the developed system is given with screenshots at each stage.

Chapter 6 gives the conclusion, recommendation, and suggestions for future studies

CHAPTER 2

RELATED RESEARCH

In this chapter is the related research on LMS evaluation by different researchers, where different studies previously published in this subject area of the research was analysed, examined their findings and also study their missing gaps.

2.1 LMS Evaluation

Karagoz et al. (2017) developed a mobile application for the comparison of two open source LMS (Moodle and Sakai) and two commercial LMS (Blackboard and SharePoint LMS) based on four criteria; License cost, flexibility, security, and market share. The comparison was performed using AHP MCDM method. The result shows that license cost is the most important among the criteria. Thus if license cost is the priority, then the best choice is Sakai. If flexibility is the priority, then Moodle is the preferred choice. While if security and market share is the priority, then Blackboard is the best choice. In general, if license cost and flexibility are the priorities then open source is the best. But if security and market share are the priorities, then commercial is the best choice.

Hock, Omar and Mahmud (2015) evaluated three OS LMS, Moodle, ATutor and Ilias based on the usability and user acceptance of the systems, latest version of each LMS was installed on computers and set all to default settings and configurations. Then same documents was uploaded to all these systems. Participants were then asked to perform 5 different tasks on each system, then fill a survey form for each LMS system used. Also time taken for each participant to finish a task on each LMS system was recorded. The result show that the participants spent less time on Moodle system than on the other two in 3 tasks. Though they spent little time on 2 tasks when using ATutor. Ilias LMS has taken much time in 5 tasks. This shows that based on this research, Moodle system is the most user friendly followed by ATutor, then Ilias.

Isik, Ince and Yigit (2015) used Fuzzy Analytic Hierarchy Process (FAHP) for the selection of the most proper LMS according to nine selected evaluation criteria i.e; multilanguage, cost, evaluation tools, compatibility, support, sustainability, reliability, source code, management. The study also considered ten alternatives for the LMS selection, that are Joomla LMS, Sum Total Systems, Moodle, Dokeous, OLIAS, Enocta, Sakai Project, Hotchalk, Blackboard, Atutor. Based on the criteria considered, Joomla LMS is the most fitting LMS that meets the requirement according to this case study.

Ramesh and Ramanathan (2013) developed a method to evaluate LMSs based on six categories of criteria (basic features, learner management features, technical features, content management, assessment and security features) which directly or indirectly affects students learning experience. A weight factor is assigned to each criterion and each LMS (Moodle and Sakai) that will be evaluated should have a score of 0-4 for each criterion based on whether requirement is met or not, the scores and the criteria weights are then multiplied together and then summed to find the total LMS score. The result shows that Moodle LMS has a higher score over Sakai based on the chosen list of criteria.

Edrees (2013) evaluated two LMSs Blackboard and Moodle based on their readiness to support Web 2.0, He identified six tools as the most popular Web 2.0 technologies and tools, wikis, blogs, RSS, podcasts, bookmarking and virtual environments. A two level evaluation method was designed in order to evaluate LMSs based on its readiness to support eLearning 2.0, experts were asked to rate each the efficiency of each tool, by identifying if the tool is built-in in the LMS and the possibility of integrating the tool in case if it is not available as built in in the LMS. A value between 1-10 is assigned to each tool, and then the cumulative score was computed for each LMS. The result shows that Moodle LMS has the highest point of 49.97 out 60 because five tools out of the 6 are available and the other one can easily be integrated, while blackboard got a point of 32.83 out of 60, in which three of the tools are not available and very difficult to integrate.

Cameroni et al. (2013) used a performance evaluation method for three open source LMS; Moodle, Sakai, and dotLRN to select the most suitable one. All the three LMS were installed on a server, the server was set to same system configuration, and share a central data base, then experiment were taken with multiple users performing different tasks to test

the system performance and the of each LMS, 90,100 and110 number of concurrent users were tested, and the average was taken. Based on system performance, Sakai and dotLRN have same rating higher than Moodle, while from administrator side, Moodle and Sakai have equal points higher than dotLRN. So if the system is expected to have many users, then the best choice should be either Sakai or dotLRN. But if simplicity and intuitive is what is needed, and the support of a large community of users, the preferred choice will be either Moodle or Sakai. Sakai is the recommended LMS because in both system performance and administrator view the result was very good.

Srdevic et al. (2012) stated that selecting the most suitable LMS involves large number of features to be considered, but He argued that a reliable result can also be attained if the number of features is reduced, He then suggested using AHP method which divides the LMS evaluation problem into smaller sub-problems in hierarchy that can be analysed independently, an expert used AHP on the developed hierarchy of the evaluation problem, where three categories of criteria are considered and also three LMSs were considered in this study, Blackboard, CLIX and Moodle. Finally, the outcome of the AHP process demonstrates that CLIX 5.0 is the most appropriate LMS. The result led to an indistinguishable outcome from the one given by the DeXi evaluation with 57 criteria.

Albarrak, Aboalsamh, and Abouzahra (2010) concentrated to the evaluation of 3 open sources LMSs Jusur, Sakai, and Moodle. The criteria considered in this study are content management, curriculum mapping and planning, learner engagement and administration and tools & services in combination with several other models to promote and enhance the evaluation procedure. The result shows that Sakai and Moodle are excellent tools, because, in the content management section, Sakai has an intuitive user interface, while in the curriculum mapping and management tools section, Moodle is very complete and perfect, in Jusur LMS, there is lack of some features though it is very perfect in localization. If integration is considered, Sakai is will be the best option.

Cetin, Isik, and Guler (2010) applied AHP method to solve LMS evaluation problem based on 9 evaluation criteria, Multi-language Support, The cost, Evaluative tools, Compatibility, Support, Sustainability, Reliability, Source Code and Management with 16 sub-criteria. Ten LMS were considered in the study as alternatives; ATutor, Black Board, Dokeos, E-

nocta, HotChalk, Ilias, Joomla, Moodle, Sakai Project, Sumtotal Systems. Based on the case study Moodle LMS got the highest percentage of 15.249% which makes it the most effective LMS among the alternatives.

Machando and Tao (2007) compared the user experience based on usability and effectiveness of two competing LMSs: the opensource Moodle and the commercial Balackboard. An online survey was performed for the comparison of the basic functionalities of each system from the viewpoint of both the university staff and the students of California State University such as communication tools and social integration. The result shows that Moodle LMS was the preferred choice over the Blackboard LMS.

Arh and Blazic (2007) developed a Multi-Attribute Decision Support Model using expert system shell, the decision process was sectioned into four categories: identifying the criteria, defining rules, description of variants and evaluation process. Three categories of criteria are considered, student's learning environment, system, technology & standards, and tutoring & didactics. The selection is done between three LMSs BlackBoard 6, Moodle 1.5.2 and CLIX 5.0, to identify the most suitable and efficient among them. Based on the decision support model results in the case study, CLIX 5.0 acquired the best result.

Table 2.1: Summary of related research

Author	Method	Criteria	LMS Evaluated
Karagoz et al. (2017)	Mobile App	License cost, flexibility, security and market share.	Moodle, Sakai, Blackboard, and Sharepoint.
Hock, Omar and Mahmud (2015)	Usability test	Usability and user acceptance	Moodle, ATutor, and Ilias
Isik, Ince and Yigit (2015)	FAHP	Multilanguage, cost, evaluation tools, compatibility, support, sustainability, reliability, source code and management.	Joomla LMS, Sum Total Systems, Moodle, Dokeous, OLIAS, Enocta, Sakai Project, Hotchalk, Blackboard, and Atutor.
Cameroni et al. (2013)	System performance	Memory size, speed, user experience, and network I/O	Moodle, Sakai, and dotLRN.
Ramesh and Ramanathan (2013)	Weight Factor	Basic features, learner management features, technical features, content management, assessment and security features.	Moodle and Sakai.
Edrees (2013)	User experience	Wikis, Blogs, RSS, Podcasts, Bookmarking and Virtual environments.	Blackboard and Moodle.
Srdevic et al. (2012)	AHP	Student's learning environment, System, technology & standards category and Tutoring & didactics.	Blackboard, CLIX, and Moodle.
Cetin, Isik, and Guler (2010)	AHP	Multi-language Support, The cost, Evaluative tools, Compatibility, Support, Sustainability, Reliability, Source Code and Management.	Atutor, Black Board, Dokeos, E-nocta, HotChalk, Ilias, Joomla, Moodle, Sakai Project and Sumtotal Systems.
Albarrak, Aboalsamh, and Abouzahra (2010)	Practical evaluation	Content Management, Curriculum mapping and planning, Learner engagement and administration and Tools and services.	Jusur, Sakai, and Moodle.
Arh and Blazic (2007)	Expert system shell	Student's learning environment, System, technology & standards and Tutoring & didactics.	BlackBoard 6, Moodle 1.5.2 and CLIX 5.0.
Machando and Tao (2007)	User experience	Usability	Moodle and Blackboard.
This thesis	Fuzzy DEMATEL-TOPSIS	Accessibility, Communicability, Compatibility, Content management, Efficiency, Error tolerance, Evaluation Tools, Flexibility, Functionality, Instructor tools, Administrator tools, Learnability, Maintainability, Multi language, Navigability, Pedagogical factor, Personalization, Portability, Reliability, Security, Support, Sustainability, System performance, Technical features, Usability, User satisfaction.	Moodle, Sakai, dotLRN, Claroline, ATutor, Ilias, Dokeous, Olat, Forma LMS and Eliademy

2.3 Summary

From the above review, it shows that there is limited research in the application of MCDM approach in LMSs evaluation, and very few of the studies use the integrated approach. The review also shows that there is a missing gap in using the fuzzy DEMATEL-TOPSIS integrated method. There are also minimal developed or proposed systems for the LMSs evaluation that will help users in LMS evaluation to get result easily and effectively.

CHAPTER 3

THEORETICAL FRAMEWORK

This chapter gives detailed explanations on web applications, fuzzy logic, MCDM, DEMATEL and TOPSIS in one side, and on the other side it give a detail explanations on LMS, its types, its features and the alternatives used in the research

3.1 Web Application

A web application is a client-server application where client-side logic operates on a web browser. It utilizes the web archives which are designed using a standard format like the HTML and JavaScript. Most of the web browser supports both the HTML and the JavaScript. Web applications generally employ a combined server-based script like the PHP and ASP, and the client scripts like HTML and JavaScript for application development. The client scripts are used to present information or data, while the server-based script takes care of the data storage and retrieval (Pinto and Stuttard, 2011).

3.1.1 Client-side development

The client side development which is also called front end development is the user interface that is been interacted with, this is the Web browser for the Web applications, and it is mostly run with javascripts.

Browser: This is a software application designed for the retrieval, display and navigating data resources on the World Wide Web. A data source is distinguished by a Uniform Resource Identifier (URI/URL) in a web page format and other sources. Despite the fact that the browsers are initially designed to utilize the World Wide Web, but they can likewise be utilized to get to data or files in a private network or file system respectively, which is administered by a web servers. Some of the most prominent browsers includes Internet Explorer, Google chrome, Firefox and Opera.

HTML: Hypertext Mark-up Language (HTML) is a language for designing web sites applications, mostly with the utilization of Cascading Style Sheets (CSS) and JavaScript. The browser get HTML reports from a web server then convert them into interactive website pages. HTML utilizes elements as the bases for its pages design which is described by a tag, represented within greater than, and less than signs. The web browsers don't show the HTML tags, yet it utilizes them to translate what will be displayed on the page.

CSS: Cascading Style Sheets (CSS) is a language utilized for portraying the introduction of a record written in a mark-up dialect. The CSS together with HTML and JavaScript, became a foundation innovation that is utilized by majority of websites to make multimedia web pages and user interfaces. CSS is built principally to allow the disconnection of presentation from the content.

JavaScript: It is a high-level programming language used together with HTML and CSS to form the pillars of web page designs. It allows the interaction with a web page, and also present online applications. It is integrated into most of the websites and is supported by all modernized browsers. There are different APIs for various objects, but doesn't on its own support any input/output like the network or data store.

3.1.2 Server-side development

The server- side development is also called the back-end side, it is a scripting technique in which the scripts are deployed on a server and runs directly from the server for each request.

PHP: PHP is a server-side scripting language designed basically for web application development, but it can also be employed as a general-purpose programming language. PHP can be inserted into HTML, or combined with many website templates, or frameworks. PHP code can be executed in a Command-Line Interface (CLI) and can also be applied to design standalone applications.

ASP.NET: This is a free and open-source server-based web application development framework intended for dynamic web pages creations, which depends on the .NET CLR (Common Language Runtime). ASP.NET applications are typically coded in C# and

Visual Basic languages. Programming in ASP.NET very much looks like the way desktop applications are produced.

***Model-View-Controller (MVC)*:** This is a programming pattern which involves the division of an application into tiers: The view, which deals with the display of data to the user. The Model, which is the data that the view normally requires to display itself to the user. Then the controller, which knots both the model and the view together. It controls the intercommunication with the user i.e. HTTP request.

This architecture has grown famous for creating web applications other clients. Most modern programming languages like Java, C# and PHP have recommended MVC frameworks that are currently being used in web application.

3.2 Fuzzy Logic

Mostly in the real life applications, decision goals and constraints are sometimes not precisely known, this makes a decision-making problems also imprecise (Zadeh, 1965). This is why fuzzy logic was introduced in the year 1965; is a decision making tool used to validate ambiguous and unclear issues, it also deals with the unreliable human decisions. Fuzzy logic is different from boolean logic that decides whether an element is in the set (1 or 0) or not, a fuzzy set determines a level of possession by a membership function. Thus, using fuzzy numbers during decision-making became very important. There are different forms of fuzzy numbers; like the triangular, trapezoidal, octagonal, pyramid, pentagonal, diamond and hexagonal fuzzy numbers (Pathinathan and Ponnivalavan, 2015) used based on certain situation at place. According to Akyuz and Celik (2015), Triangular Fuzzy Number (TFN) is more preferred to be used in evaluation and it is the most generally used fuzzy representation. For this reason, this study adopts the TFN which can be defined based on three parameters as A = (l, m, n) where l, m and u denote smallest, intermediate and highest value in the fuzzy sets $(x \leq y \leq z)$.The membership function of a TFN $\mu\_(A)$ is defined as shows below (Tuzkaya and Onut, 2008).

$$\mu_A = \begin{cases} 0 & x - l \\ (x-l)/(m-l) & l \le x \le m \\ (u-x)/(u-m) & m \le x \le u \\ 0 & x \ge u \end{cases}$$

This type of fuzzy number consists of the set of three real numbers ranging from minimum, most expected and maximum weights. The Figure below depicts the triangular fuzzy number with its three values.

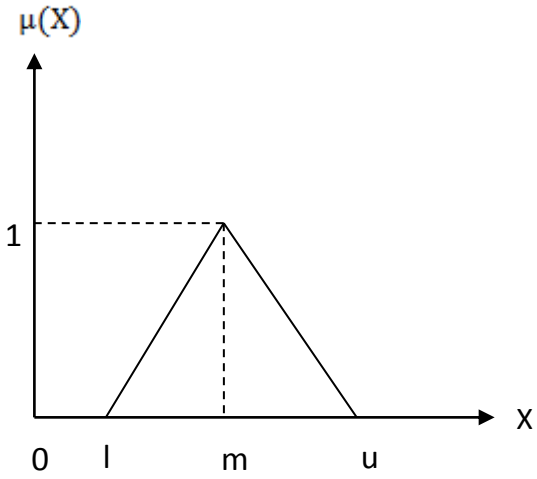

Figure 3.1: Triangular fuzzy number

The Best Non-fuzzy Performance (BNP) defuzzification method is one of the techniques used in defuzzifying the fuzzy values into crisp values (Mohammadi, Nouri and Ehsanifar, 2013). BNP of a TFN $a = (l, m, n)$ can be expressed as:

$$BNP = l + \frac{(u-l)+(m-l)}{3} \qquad (3.1)$$

3.3 Multi Criteria Decision Making

Multi Criteria Decision Making (MCDM) is a discipline which deals with the evaluation of various differing criteria in a decision making (Dursun and Arslan, 2016). It structures and solves decision and outlining issues associated with multiple criteria. The objective is helping decision-makers having such issues. The decision-makers priority is used to discriminate among solutions, because such issues cannot have a single resolution, so using decision-makers choices became essential in the discrimination among solutions. It

likewise has some exceptional qualities, for example, the presence of various non-commensurable and differing criteria, distinctive units of measurement among the criteria, and the presence of several alternatives. It is an attempt to survey the different MCDM techniques and need was felt of further advanced methods for practical validation and testing of the various available approaches for the extension of MCDM into collective decision-making circumstances for the treatment of uncertainty. The MCDM is getting interested as possible means for examining complicated real-life issues due to their strength in assessing various alternatives on multiple criteria for viable choice of the best alternative (Ortiz, Felizzola and Isaza, 2015). The basic structure of the MCDM technique is shown in Figure 3.2 below

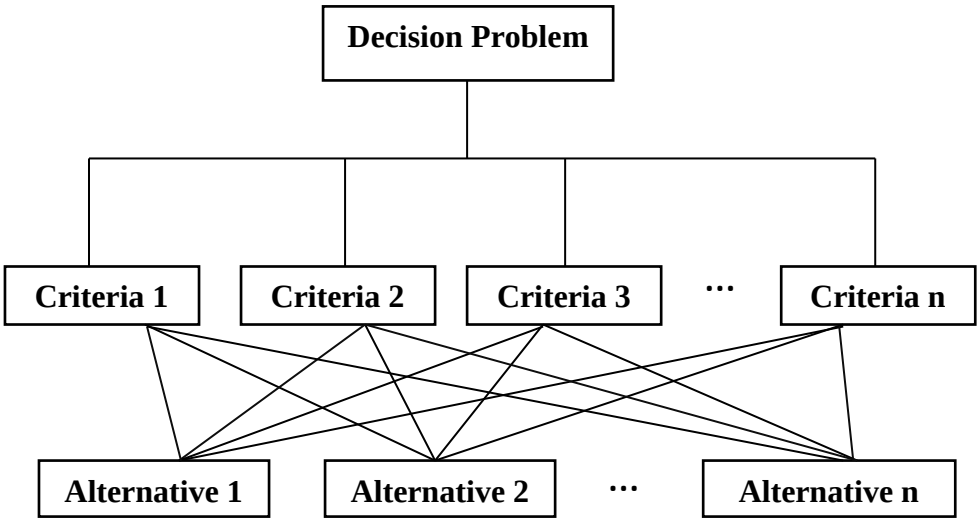

Figure 3.2: Multi criteria decision making tree (Ergu et al., 2014)

3.3.1 DEMATEL

The DEMATEL method was introduced in 1973 by Geneva to solve complicated and unclear issue (Shieh, Wu and Huang, 2010). It is a complete instrument used to analyze and build a basic model which involves cause and effect relationships between complicated factors (Wu and Lee, 2007). The technique is been applied to transform the relationship between criteria, causal measurements from an unpredictable to a justifiable model of the chosen system (Dalalah et al., 2011). In particular, the final result in the DEMATEL procedure is a visual representation of digraphs, which separates components into cause and effect groups. Also, Akyuz and Celik (2015) stressed that DEMATEL is generally

being identified as among best functional technique in finding the cause and effect relationship among assessed criteria in the evaluation process of any system or product. Another advantage by Tzeng, Chiang and Li (2007) is that when DEMATEL method is used, the number of chosen criteria for evaluation will decrease, which will be beneficial for organizations in enhancing efficiency of particular factor in view of the effect digraph map.

In reality, crisp values are not effective because human judgments are mostly indistinct and difficult to assess by exact crisp values, due to imperfection of some assessment criteria and even uncertain factors. This is why fuzzy theory is being used on the DEMATEL method as suggested by Lin and Wu (2008) to tackle such type of MCDM issues. Fuzzy DEMATEL method is applied in different area of research to solve different MCDM problem (Chang, Chang and Wu, 2011; Mohammadi, Nouri and Ehsanifar, 2013; Akyuz and Celik, 2015).

In this thesis also, fuzzy DEMATEL technique has been employed by the authors to find the relationships between the identified LMS evaluation criteria. According to Dalalah et al. (2011), this technique is very useful in discovering the connections among elements and requesting the criteria in view of the kind of connections and seriousness of their consequences for each other criteria. The step by step procedure involves in fuzzy DEMATEL method is as shown below:

Step 1: Defining a decision goal, constructing fuzzy scale as well as list of criteria, then determine the initial relation matrix which is obtained by LMS expert's opinion on the relationship between the criteria, the comparison is based on five points fuzzy linguistic scale of 0-4 which is mostly being used for evaluation methods in the literature where scores of 0 represent "no influence'', 1 represent ''low influence", 2 represent "normal influence", 3 represent ''high influence'', and 4 represent ''very high influence'' as shown in below.

Table 3.1: Fuzzy linguistic scale (Lin, 2013)

Linguistic terms	Influence score	Triangular fuzzy number
No influence	0	(0,0.1,0.3)
Very low influence	1	(0.1,0.3,0.5)
Low influence	2	(0.3,0.5,0.7)
High influence	3	(0.5,0.7,0.9)
Very high influence	4	(0.7,0.9,1)

Opinions of the K respondents can be incorporated as the initial relation matrix $A = [a_{ij}]n \times n$ can be built as shown below (Tzeng et al., 2007):

$$A = \begin{bmatrix} a_{11} & \cdots & a_{1j} & \cdots & a_{1n} \\ \vdots & & \vdots & & \vdots \\ a_{i1} & \cdots & a_{ij} & \cdots & a_{in} \\ \vdots & & \vdots & & \vdots \\ a_{n1} & \cdots & a_{nj} & \cdots & a_{nn} \end{bmatrix}$$

Step 2: Normalization of the initial relational matrix which is calculated as shown below.

$$N = K \text{ x } A \tag{3.2}$$

Where

$$K = \frac{1}{\max\limits_{1 \le i \le n} \sum_{j=1}^{n} a_{ij}}, i, j = 1,2...n \tag{3.3}$$

Step 3: Computation of total-relational matrix. The total-relational matrix T is represented as:

$$T = N(I - N)^{-1} \tag{3.4}$$

I here an identity matrix, while t_{ij} means the level in which criterion C_i has impact on criterionC_j.

Step 4: Compute the total impact received and given by all criteria. Let D and R be the vectors:

$$D = \left[\sum_{i=1}^{n} t_{ij}\right]_{n\times 1} = \left[t_i\right]_{n\times 1} \tag{3.5}$$

$$R = \left[\sum_{i=1}^{n} t_{ij}\right]_{n\times 1} = \left[t_j\right]_{n\times 1} \tag{3.6}$$

Where D and R is the sum of the horizontal and the vertical cells of the total-relation matrix T.

Step 5: Compute the relative importance of criterion using the following formula:

$$w_i = \{(D_i + R_i)^2 + (D_i - R_i)^2\}^{1/2} \tag{3.7}$$

Step 6: The normalized weight of each criteria is calculated as

$$w_i = \frac{\omega_i}{max_{1\leq i\leq n}(\omega_i)} \tag{3.8}$$

3.3.2 TOPSIS

TOPSIS is among the most common techniques used in tackling MCDM problems; it was initially introduced in 1981. Mostly it is been applied to measure the relative value of alternatives and resolving decision-making problems because it has a powerful computational performance and comprehensibility. Furthermore, many researchers have applied TOPSIS in solving different MCDM problems (Wang and Lee, 2009; Deng and Chan, 2011; Bhattacharjee, et al., 2017). The main concept of this method assumes that a preferred choice will closest from the positive ideal solution (PIS) and the farthest from the negative ideal solution (NIS) (Shih et al., 2007). The TOPSIS technique steps are as shown:

Step 1: Build the decision matrix Q, which contains ‘a’ alternatives associated with ‘c’ attributes.

$$Q = \begin{array}{c} \\ C_1 \\ C_2 \\ \vdots \\ C_m \end{array} \begin{array}{c} \begin{array}{cccc} A_1 & A_2 & \cdots & A_n \end{array} \\ \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \end{array}$$

Step 2: Normalize the decision matrix by changing the parameters orientation into non orientated parameters, which permits inter-relating the criteria. The normalization scores are as shown:

$$r_{ij} = \left(\frac{a_{ij}}{c^+{}_j}, \frac{b_{ij}}{c^+{}_j}, \frac{c_{ij}}{c^+{}_j}\right) \; c^+{}_j = \max c_{ij} \tag{3.9}$$

$$r_{ij} = \left(\frac{a^-{}_j}{c_{ij}}, \frac{a^-{}_j}{b_{ij}}, \frac{a^-{}_j}{a_{ij}}\right) \; a^-{}_j = \min a_{ij} \tag{3.10}$$

Step 3: Weighting the normalized decision matrix: Let w_i be the weights of the criteria for i = 1…n. Then, take the product of each weight with its associated column of the normalized decision matrix. The weights used here are the once already calculated from fuzzy DEMATEL method as in Equation 3.8. The product of the weights and the decision matrix forms a new matrix as shown below:

$$v_{ij} = r_{ij} \times w_{ij} \tag{3.11}$$

v_{ij} is the weighted normalized decision matrix.

Step 4: Calculate the Fuzzy Positive Ideal Solution (FPIS) and the Fuzzy Negative Ideal Solution (FNIS) of the alternatives using the formula below:

$$A^+ = (v_1^+, v_1^+, \ldots, v_n^+) \tag{3.12}$$

$$A^- = (v_1^-, v_1^-, \ldots, v_n^-) \tag{3.13}$$

Step 5: Find the distances of alternatives from Fuzzy Positive Ideal Reference Points (FPIRP) and Fuzzy Negative Ideal Reference Points (FNIRP)

$$\mathrm{d}_\mathrm{i}^+ = \sqrt{\textstyle\sum_{\mathrm{j}=1}^{\mathrm{n}} (v_{\mathrm{ij}} - v_{\mathrm{j}}^+)^2}, \mathrm{j} = 1,2,\ldots,\mathrm{j} \tag{3.14}$$

$$d_i^- = \sqrt{\sum_{j=1}^{n}(v_{ij} - v_j^-)^2},\ \mathrm{j} = 1,2,\ldots,\mathrm{j} \quad (3.15)$$

Step 6: Calculate the closeness coefficient (CC_i) of each alternative, which is the distances from the fuzzy A^+ and the fuzzy A^- altogether. It is computed as:

$$CC_i = \frac{d_i^-}{d_i^+ + d_i^-}, \quad i = 1,2,\ldots,m \quad (3.16)$$

Step 7: Ranking of the alternatives: Here, the alternatives are ranked based on the CC_i in descending order. The best choice is the one that is closest to the FPIS and the most far away from the FNIS.

3.4 Learning Management System

Learning Management System is a software product used in organization, documenting, following-up, reporting as well as conveyance of educational courses or training programs (Cavus, 2013). LMS starts from multimedia tools like audio/video CD/DVD to highly advanced software that manages educational institution (Sedivy, 2011). Mostly, standard LMS can perform various e-learning tasks, like allowing students to have access to learning materials, enabling online chart (audio, video) between students and instructors, self-assessment and many others (Cavus and Alhih, 2014).

LMS is controlling the management, tracking and reporting the interaction between the student and the substance, then the student and the instructors (Rafi, Samsudin and Hanafi, 2015). LMS performs student enrolment, track student progress, take account of test scores, and show course completion, lastly enable instructors to evaluate the performance of their students (Macfadyen and Dawson, 2010).

3.4.1 History of Learning Management System

The aim of simplifying the education process, making it better and faster by making use of computer has been around for many years. This makes LMS to be progressively attractive in the past couple of years, where specialized advancements have re-imagined the instructing and learning processes. LMSs history started in the mid twentieth century from a simple machine that looks like a typewriter, and it continued to develop up to the current

advanced cloud-based systems (Carmen, Davis and Wagner, 2009). Table 3.2 shows the LMS development histories since from its first invent in 1924 till date.

Table 3.2: History of learning management systems

Year	History
1924	The first LMS was developed by Sidney Pressey (a professor of psychology at Ohio State University) in the year 1924. He invented the first 'the teaching machine' which looks similar to a typewriter with an opening that could administer questions. One opening was used to show the question and the other one to fill in the appropriate response (https://www.easy-lms.com/help/lms-knowledge-center/history-of-lms/item10401, Retrieved 20, October, 2017).
1929	In this year, 'problem cylinder' was designed by M.E. Lazerte. It exhibited a problem to a student and checked whether the solution steps taken by the student were correct (https://www.learndash.com/history-of-the-lms/, Retrieved 20, October, 2017).
1956	The world's first adaptive teaching system SAKI (Self-Adaptive Keyboard Instructor) was developed by two engineers Gordon and Robin. This keyboard based console was designed to help individuals type very fast and accurate. It imitated the teacher and student relationship in which it can decide the questions to be given to the learner based on his performance level (https://www.mindflash.com/learning-management-systems/history-of-lms, Retrieved 20, October, 2017).
1983	MIT launches its project Athena (computer-based learning tools) after 8 years of research. The platform is being used at MIT, it also permits third party educational programs to be integrated (https://www.synotive.com/blog/history-of-learning-management-system-lms, Retrieved 20, October 2017).
1990	First-class is named as the first LMS which is developed by Soft Arc. It was the first ever LMS software for Macintosh platform, as opposed to systems that run on a centralized server PC like past learning systems (https://www.easy-lms.com/help/lms-knowledge-center/history-of-lms/item10401, Retrieved 20, October, 2017)..
1997	Course Info developed the first LMS with a relational database (MySQL) called Interactive Learning Network. The system was lunched at Yale, Cornell, and other academic institutions (https://www.easy-lms.com/help/lms-knowledge-center/history-of-lms/item10401, Retrieved 20, October 2017).
2002	"Moodle" an open-source internal system was introduced by Martin Dougiamas. The system has 3 user's platform. The administrator makes courses for instructors and manages other system settings. The instructor manages at least one subject and can enter student's information. Students can be enrolled in a different subject who they have been registered. The Moodle system has more than 60.000.000 clients in 65.000 schools and is been used in over 216 countries (https://www.mindflash.com/learning-management-systems/history-of-lms, Retrieved 20, October, 2017).
2004	A set of standards for training technology called SCORM (Shareable Content Object Reference Model) was introduced which serve as a platform for various current LMSs (https://www.mindflash.com/learning-management-systems/history-of-lms, Retrieved 20, October, 2017).
2008	The first open source application programming interface (API) called Eucalyptus was released when the private clouds are about to be deployed. This makes it possible that an LMS need not to be installed on a pc or network, it can operate fully online (https://www.learndash.com/history-of-the-lms/, Retrieved 20, October, 2017).
2012	Presently, SaaS LMSs benefited the cloud-based technologies. Institutions and organizations got it very much easier, that they don't have to develop or install the system. Also, there are different LMS applications that support mobile devices using Wi-Fi (https://www.learndash.com/history-of-the-lms/, Retrieved 20, October, 2017).

3.4.2 Types of LMS

Learning management systems like many other softwares can be accessible in two forms; the commercial and the Open Source versions:

3.4.2.1 Commercial LMS

Commercial software is software product designed and licensed to end users or serves for commercial purpose (Krishnamurthy and Tripathi, 2014). Although commercial software was once considered as the domain of proprietary software, currently the open-source applications have also become commercial software, licensed to customers (Ghapanchi, 2014). In commercial LMS releases, the main categories are of two forms: Installed, or the service-based cloud option.

LMSs are also available in the proprietary form; i.e. a user needs to purchase a license for him to have access to the full features of the system. Some of the top commercial LMSs are: Blackboard, Desire to learn and WebCT (Cavus, Uzunboylu and Ibrahim, 2006).

3.4.2.2 Open Source LMS

Open Source development is been around since 1960's (Bagozzi and Dholakia, 2006), but it was not given much attention until in the recent years. Initially, softwares are for commercial purposes. So, the source code of the software is private and confidential, and can only be accessed and changed by the software producing team. This restriction of the source code became a problem to the user, and there is a need for software to be open so that users can have full access to the software, modify it to suit their requirements (Bagozzi and Dholakia, 2006).

Different companies began showing interest in OSS development after its introduction in the year 1998 (Stam, 2008). OSS offers the source code along with the software, at no charge (Bagozzi and Dholakia, 2006). This gives users the ability to modify the codes, add or remove some features, and so on. Every individual can participate in the software development project (Materu, 2004). OSS developers work in group willingly to develop and modify a product they need (Osterloh and Rota, 2007).

There are numerous Open Source (OS) LMS available for use in educational institutions and organisations, but according to Abdullateef (2015), Moodle is the most commonly used Open Source LMS, followed by Sakai system, and then dotLRN, Claroline, and aTutor systems came as third, fourth and fifth respectively. Elabnody (2015) outlined the top 10 Open Source LMS as: Moodle, Sakai, Canvas, Dokeos, Olat, dotLRN, eFront, Latitude Learnimg LMS, Chamiloand and Totara KMS. Also according to Education Technology website (https://educationaltechnology.net/free-open-source-learning-management-systems/, Retrieved 12, December, 2017) the top 14 OS LMS are: Moodle, Sakai, Coursesite, Ilias, Atutor, Canvas, Elms, Kornukopia, Open edX LMS Chamilo Lms, Claroline Connect, Forma LMS, Eliademy And Olat. Based on these 3 results, this thesis considered the top ten OS LMSs as: Moodle, Sakai, dotLRN, Claroline, ATutor, Ilias, Dokeous, Olat, Edmodo and Canvas.

3.4.3.1 MOODLE

Moodle is a free and open source LMS designed by an Australian company using PHP to design web pages that has online learning materials, and courses for trainings, interactions, collaboration and the delivery of learning material (Cavus, 2015). An instructor can manage at least one subject and can also enter student's information. While students can be enrolled in a different subject who they have been registered. It was originally developed by Martin Dougiamas, where the first version was released in August 2002. Currently according to Moodle website, there is about 123,647,583 clients in 93,159 registered sites and is been used in 234 countries around the world (https://moodle.net/stats/, Retrieved 20, December 2017).

Moodle has an outstanding documentation, powerful support tools for both security and administration. The software helps instructors in designing and delivering online course material to students (Cavus, 2015). Moodle LMS can be accessed through https://www.moodle.org/.

3.4.3.2 SAKAI

Sakai is a free and open source LMS formed as a result of a collaboration of four leading US universities. Each institution offered its present tools. Mellon foundation initially

financed the project. The main aim of the collaboration is to bring an improvement of the teaching and learning as well as educational research by providing an alternative to each institution's own leaning system.

Sakai is developed in java, and version 1.0 became freely available in March, 2005. Sakai community has successfully deployed multiple releases after its first release. Now there are hundreds of institutions that use Sakai with over 1.25 million students in the U.S and over 4 million students globally (https://www.sakaiproject.org/about, Retrieved 20, December, 2017). The Sakai LMS has been translated into more than 20 different languages. Sakai is initially administered by Sakai foundation which was later merged with Jasig in December 2012 and Apereo foundation took over. Sakai LMS can be accessed through https://www.sakaiproject.org/.

3.4.3.3 dotLRN

dotLRN is an open source LMS initially created at MIT with an advanced entry framework that incorporates devices for course and substance organization and collective tools. It is being adopted worldwide by over 500 thousand clients in educational institutions, government and organisations (Bayon, Santosand Boticario, 2008). It has the favorable position in that just a single arrangement of learning plan and runtime devices at that point should be actualized keeping in mind the end goal to support various instructional methods. dotLRN involves group of educators, developers worldwide who accomplice together to drive instructive advancement. DotLRN LMS can be accessed through http://www.dotlrn.org/.

3.4.3.4 Claroline

Claroline is an OS LMS designed collaboratively by a French university, it was developed as an alternative to some commercial learning management systems. It allows educational institutions and organisations to create and manage course material and also provide online interaction platform. This software is been used in 100 countries and is available in 35 different languages (Cavus and Zabadi, 2014). Claroline programming team are concentrating on improving the features that will meet user requirements. Their principal interest isn't to develop many features, but to think upon some of improvement tools

related to the educational and the interface offered to the user (Peraza et al., 2012). Claroline LMS can be accessed through https://www.claroline.net/EN/index.html.

3.4.3.5 ATutor

ATutor is an open source LMS developed as the result of series of researches carried out in the year 2001, which studied the accessibility of disabled people to the online learning systems (Khaimook, 2010). The outcomes of the studies revealed that not a single LMS of the top LMS softwares implemented even the minimal accessibility features. This is the reason why developers designed ATutor LMS in the late 2001, which made it the first LCMS to have the full accessibility feature that comply with the W3C WCAG 1.0 standard. ATutor can be utilized in different circumstances, which includes course management, instructor's professional development, career development, and academic research. It is also being used globally and supports over fifteen languages. (Abdullateef et al., 2015). ATutor LMS can be accessed through http://www.atutor.ca/.

3.4.3.6 ILIAS

ILIAS is an acronym for (Integrated Learning, Information and Work Cooperation System). It is a free and online-based LMS which provide a soft atmosphere for using the integrated tools in learning online. It is one of the pioneer LMSs that have been used in schools (Wharekura-Tinia and Aotearoa, 2004). The first prototype was developed as a project in University of Cologne in the year 1997, and version 1 of ILIAS LMS was released and used as a tool for learning in two departments in the university. Later, other universities show interest in the application, in 2000, they distributed ILIAS as open source software under the General Public License (GPL) which can be operated on all PHP and MySQL supported server. Another version of ILIAS was designed from scratch between 2002 and 2004 and called ILIAS 3. ILIAS 3.9 was released in 2007, and became Sharable Content Object Reference Model (SCORM) 2004 compliance (Aberdour, 2007). The newer reliese of ILIAS 5.2 is PHP 7 compliance, and it includes the assessment object, chat rooms, and many other features. Ilias LMS can be accessed through https://www.ilias.de/docu/goto_docu_root_1.html.

3.4.3.7 Dokeous

Dokeos is an easy and user friendly LMS which is the pioneer that incorporates online authorship, collaboration and video conference in the same application. It is also the main LMS that flawlessly incorporates FDA and EMA consistence and review capacity to guarantee precise representative approval and itemized revealing and administration devices (Elabnody, 2015). It is developed collaboratively as free software under the GNU GPL in the sense that it incorporates contributors from a several colleges, schools, and different associations and people. It is likewise ensured by the OSI and can be utilized as a content management system (CMS) for training and instructors, since it permits to associate with different members through tools, like the, groups and forums. They incorporated about 34 languages as of 2007, and also they have about 9900 subscribed organisations (Babic et al., 2010). Dokeos version 1.8.6.1 was released in 2010 which supports records import with SCORM 1.2. Client information can be imported in CSV or XML forms. Dokeos LMS can be accessed through https://www.dokeos.com/.

3.4.3.8 Olat

OLAT stands for (Online Learning And Training). It is a LMS that supports any sort of web based learning, instructing, and coaching with some limitations. OLAT is free and open source LM started to be developed in 1999 as version 3.0 at the University of Zurich (Keles and Ozel 2016). OLAT has supports different standards of E-learning, like the IMS and SCORM. Newer versions 4.0, 5.0, 6.0 and OLAT 7.0 have been released later with additional features like course wizard and the usage of vital benchmarks which is getting more patronage with thousands of users particularly in the European high schools and colleges, due to its sustainability for several years. OpenOLAT was released early 2012 as 8.0 (Elabnody, 2015). Olat LMS can be accessed through http://www.id.uzh.ch/de/dl/elearning/services/olatunizh.html.

3.4.3.9 Edmodo

Edmodo is a LMS founded in 2008 which allows a discussion, collaboration, and teaching platform for high schools, universities, and instructors. The Edmodo enables instructors to administer content, deliver tests, assignments, and supervise students association with

guardians (Thien et al., 2013). Edmodo is highly instructor driven by which students and guardians can just join Edmodo if they are invited by an instructor. Teachers and students invest a lot of time in the platform, inside or outside the classroom. Edmodo declared that they have 87,637,813 clients around the world and about 50% of these clients were in the USA, with the rest being in 180 nations around the globe (https://www.edmodo.com/about, Retrieved 20, December, 2017). Edmodo can be accessed through https://www.edmodo.com/.

3.4.3.10 Canvas

Canvas is a free LMS developed in 2001 by Instructure Inc. to promote and advance the development of new LMSs. It is completely cloud-native software package operated as a software as a service (SaaS) with amazon cloud services. It was programmed under Ruby on Rails framework and PostgreSQL database. It also complies with the OAuth standard, which main function is restricting access to some user's information on some social networking sites. Over than 300 institutions and collages with about 9 million users are using the software as by 2013. In the same year, the company was able to secure $30 million of funds, which makes the total funding of $50M. While in 2015, they got additional $40 Million of funds, which makes total of $90M. In 2012, the company releases Canvas K-12, it is a system developed to fulfil a specific need of primary and secondary schools. It provides a platform in which parents can track and access their child's progress and learning experience (Elabnody, 2015). Canvas LMS can be accssed through https://www.canvaslms.com/.

3.4.4 Features of Learning Management

All the LMS packages has its own unique element, and features, the literature reviewed other studies, analyse and choose the following most common features to be included in the developed LMS evaluation system. The features they are shown in table 3.3 below:

Table 3.3: LMS evaluation features with descriptions

	FEATURES	DESCRIPTION	REFERENCE
1	Accessibility	Ability for the disabled students and teachers to have full access to the LMS without any limitation.	Radwan et al. (2016)
2	Administrator tools	This is a panel that has the general system settings and configurations, like add/remove user, backup and restoration.	Pina (2018)
3	Communicability	It provides a discussion forums and chat rooms, email messages, audio and video conferences	Ramos, Penalvo, and González (2014)
4	Compatibility	Ability of the sytem to run on cross platforms, (compatible with different operating systems, platforms and modern web browsers).	McKenna, Baxter and Hainey (2016)
5	Content management	Provide a platform to create and manage, and update multiple courses or information to be delivered to the users.	Yildirim et al. (2004)
6	Efficiency	It is the ability to run within minimal of time and effort, and to be competent in its performance.	Padayachee, Kotze, and Merwe (2010)
7	Error recovery	How the system detect and recover from error, time and number of tasks performed during the recovery.	Radwan et al. (2016)
8	Evaluation tools	These are tools used to test and record learner's performance for each course.	Sanna and Marcialis (2017)
9	Flexibility	Ability to modify the system i.e. add /remove something to suit requirement.	Karagoz et al. (2017)
10	Functionality	Is the measurement of how well the software performs - ease of use and suitability for the purpose that it was intended for.	Padayachee, Kotze, and Merwe (2010)
11	Instruction tools	Tools that supports the student learning, like the whiteboards, posters, Google collaboration tools, and wikis tools.	Malone (2015)
12	Learnability	Ability to learn and use the system within the appropriate time	Radwan et al. (2016)
13	Maintainability	How the system can be easily and quickly upgraded and restored to its normal operation after a failure or error occurs.	Padayachee, Kotze, and Merwe (2010)
14	Multilanguage	Having mul-tiple languages in the system interface and resources.	Taechatanasat, Armstrong, and Nilsook (2016)
15	Navigability	Easy to use and functional navigation within the system	Radwan et al. (2016)
16	Pedagogical factor	These are features that are related to the education i.e teaching and learning.	Novakovich (2016)
17	Personalisation	This is the ability to customise, change and make possession the system.	Nicholas (2017)
18	Portability	Ability to be carried along and access from everywhere and anytime.	Padayachee, Kotze, and Merwe (2010)
19	Reliability	Ability to maintain its perform consistently based on its specifications for a long period of time.	Padayachee, Kotze, and Merwe (2010)
20	Security	Security involves user access authentication, it also involves data authorisation and integrity in which a particular access rights is given to a particular user, where it decides what the user is allowed to do.	Taechatanasat, Armstrong and Nilsook (2016)
21	Support	This is a tool which help the learners how to use the LMS by providing a user manual or guide, it also provide an online assistance with immediate feedback to LMSs' users using email or telephone helpdesk.	Amir et al. (2016)
22	Sustainability	Ability to retain its performance and maintainable for a long period of time.	El Tantawi et al. (2015)
23	Usability	The capability of the software product to be very intuitive, understood, and easy to use and learn under specified conditions.	Padayachee, Kotze and Merwe (2010)
24	User satisfaction	How much does the system meets the user's needs and expectations.	Radwan et al. (2016)

CHAPTER 4

DEVELOPED SYSTEM

This chapter gives the detail description of the applications and tools used in the web based LMS evaluation system development. It explains the Software Development Life Cycle and the set of activities performed at each development stage. It also shows the developed system architecture, system flow-chart and use case diagrams, which gives a visual representation of the design of the developed system.

4.1 Software Development Life Cycle

Software development life cycle (SDLC) is the steps followed by a software developer for a well-organized design, development, and maintenance of the software product and to assure that all the user needs are satisfied with minimum resources and time (Modi, Singh and Chauhan, 2017). Each activity is performed at one of the SDLC stage. SDLC is used to increase the quality of software within a definite time based on customer requirement. Each SDLC model comprises of a different set of tasks; like requirements and analysis, system analysis, system design, coding, testing, implementation (Barjtya, Sharma and Rani, 2017).

At the beginning of the software process cycle, the software development model to be used should be determined. In this thesis the waterfall model was chosen as the SDLC model, because of the following advantages: The advantages of the waterfall model according to (Balaji and Murugaiyan, 2012) are:

- It has a well sequential and defined stages.
- It is very easy.
- Minimise error because of unit testing.

The waterfall model comprises of five parts; analysis, design, implementation, testing and Maintenance. The steps of this model is shown in Figure 4.1.

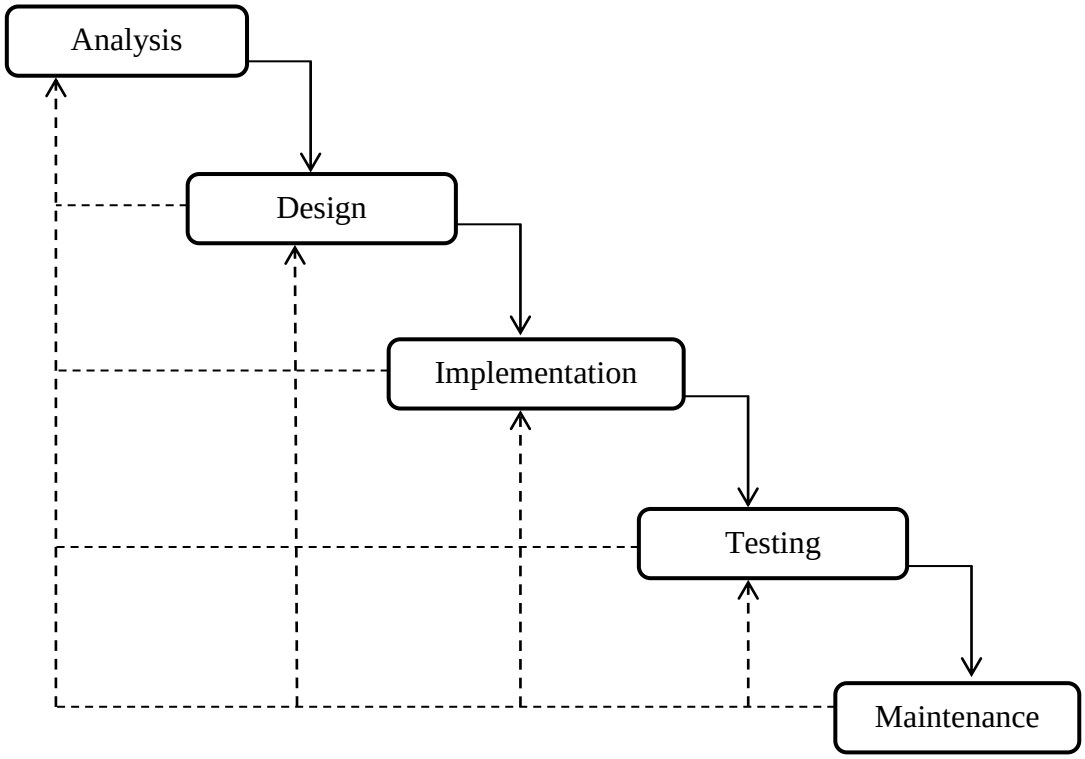

Figure 4.1: Waterfall model (Bassil, 2012)

4.1.1 Analysis

This stage involves all the information and data that will be required for the successful development of the LMS evaluation system. The requirements includes

- The technique or procedure should be defined properly.
- Evaluation criteria should also be defined.
- LMSs alternatives should also be defined.

A- Evaluation procedure

The evaluation procedure has a number of steps to be followed in order to be completed. An evaluator should follow these steps to get a valid result. An evaluator is also required to give some values and entries, which will then be fuzzified. At the end of the evaluation process, the aim is get one result, referred to as the best alternative of the LMS. For every evaluation process, the evaluator will be needed to give a set of entries which depends on his rating of the evaluation elements. Figure 4.2 shows the proposed LMS evaluation framework. Below is the set of the steps necessary for a complete evaluation operation:

Step 1: A user should first select the number of feature needed for the LMS evaluation.

Step 2: A user should also select the number of LMS alternatives to participate in the evaluation process.

Step 3: A user should give a pairwise comparison of the features selected in nxn matrix form called A. This is the influence of the criteria over one another using the scale; Very high influence (VH), High influence (H), Low influence (L), Very low influence (VL) or No influence (No).

Step 4: A user should then rate each alternative with respect to the feature selected. The rating gives the degree of effectiveness and performance of each feature in each LMS.

Step 5: The pairwise comparison matrix will then be converted to TFN of the form A= (l, m, u).

Step 6: A direct relational matrix is calculated by defuzzifying the linguistic variables to crisp values.

Step 7: The normalized matrix N will then be calculated by multiplying the initial matrix with by K, where K is the minimum of the sum of rows and columns of the initial matrix.

Step 8: The total matrix T will be calculated by multiplying the normalized matrix with the difference of the identity matrix and the normalized matrix.

Step 9: The sum of the rows D, and the sum of the columns R of the total matrix, and also the sum and difference of D and R is calculated.

Step 10: The weight of each criteria is calculated by taking the square root of the sum of the squares of D+R and D-R.

Step 11: Normalize matrix of the preference is calculated by multiplying the alternavive rating matrix Q by the corresponding criteria weights.

Step 12: The PIS (A^+) and NIS (A^-) are found by taking the set of the maximum values of each criteria in the matrix V, and the sets of the minimum values of each criteria in the matrix V respectively.

Step 13: The ideal distance d_i^+ and d_i^- of each LMS alternative from is arrived by taking the summations of the squares of difference between v_{ij} from matrix A and v_i^+ from matrix A^+, while d_i^- is the summations of the squares of difference between v_{ij} from matrix A and v_i^- from matrix A^-.

Step 14: The relative closeness of each alternative to the ideal solution CC_i is calculated by dividing the d_i^- by the summation of d_i^- and d_i^+. The ranking of alternatives is then decided by comparing CC_i values. The ranking order of all alternatives is from the highest to the lowest values of CC_i. The LMS alternative with highest CC_i will be the best choice.

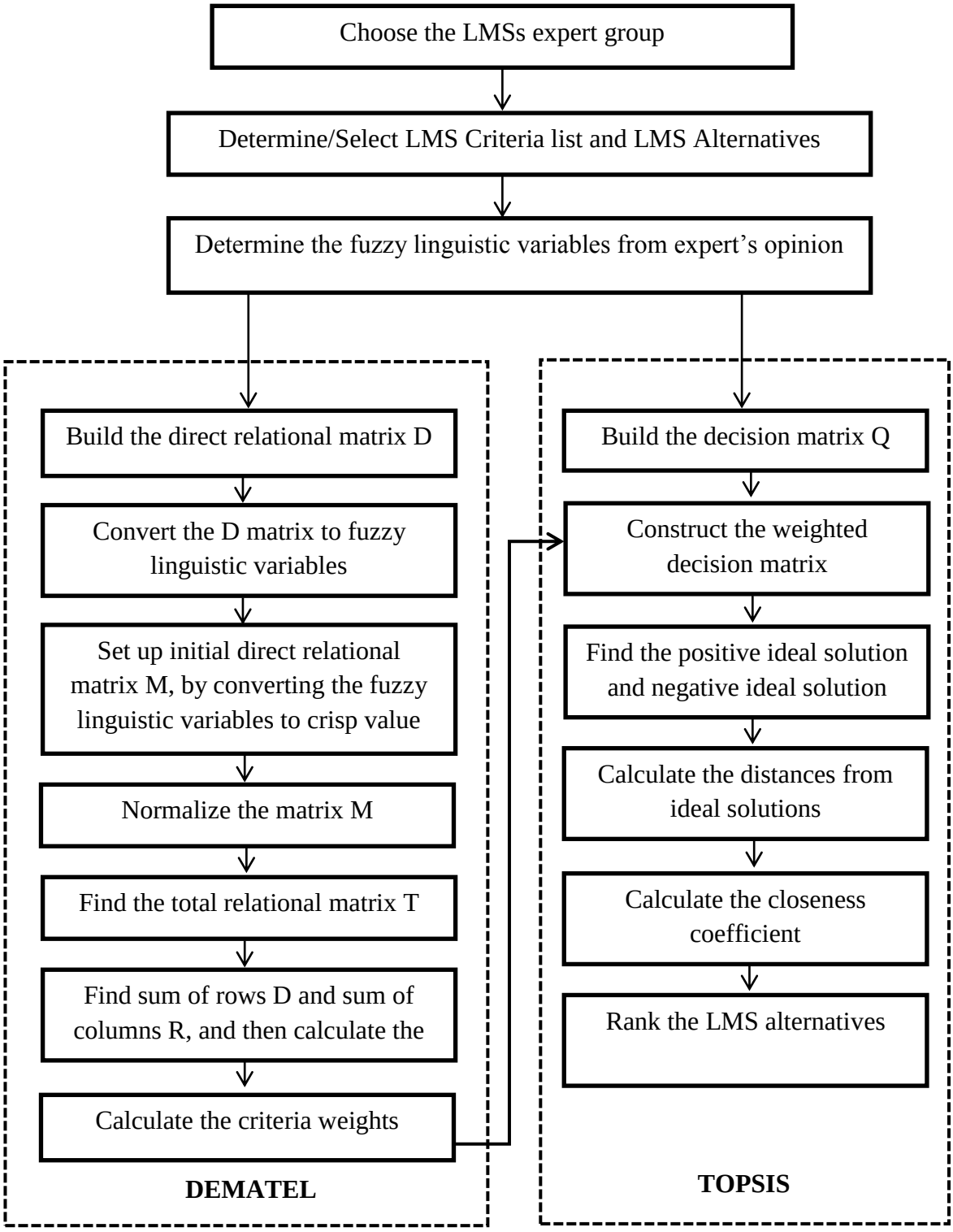

Figure 4.2: Developed system evaluation framework

4.1.2 Design

After the requirements specifications then comes the design phase which involves the design of an inner structure of the whole system, the modules and classes that the system needs, and the inter relations among all classes and modules in the system are specified. If the software structure is not well designed, then the system will be difficult to build, test or maintain.

A- The developed system

The aim of this thesis is to develop a system to evaluate and select the best LMS option out of different alternative using an integrated fuzzy MCDM technique. Therefore, in the system, a TOPSIS method will be used to rank the LMS alternatives it will be used in combination with fuzzy DEMATEL, which determines the most important criteria and their weights. The criteria that are considered in this study for the LMS evaluation have been collected from the related research section. Figure 4.3 below shows the architectural design of the proposed system

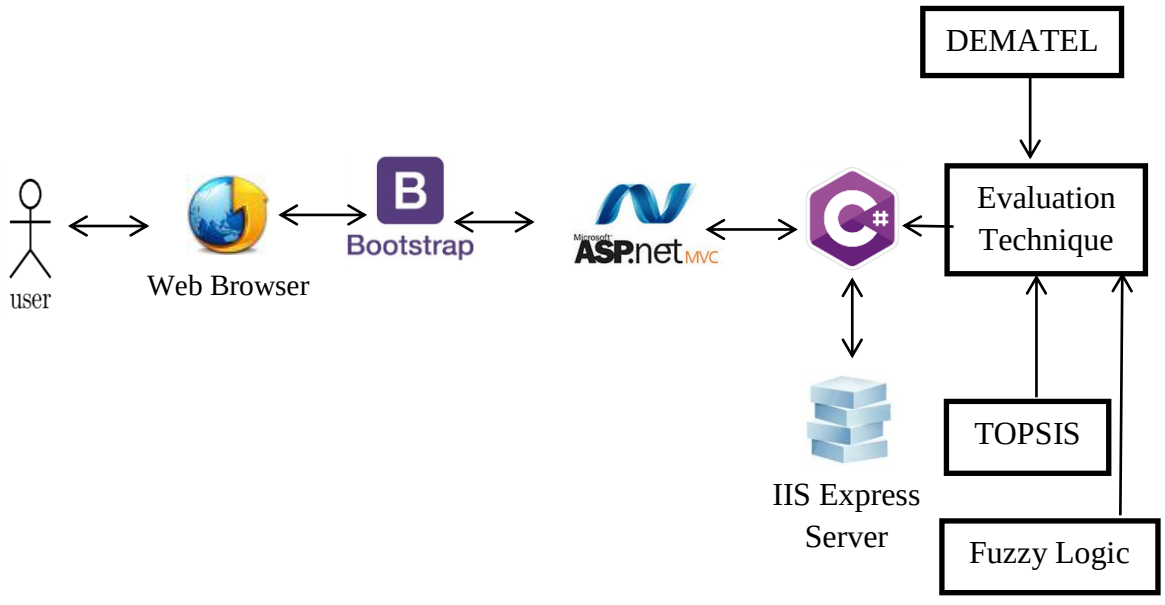

Figure 4.3: Architecture of the developed system

The various components of the developed system are described below:

- ***User*:** User refers to the individual who makes the decision, give the ratings of the alternative and interact with the system directly
- ***Browser*:** This is the front-end of the application, it is the means that the user can interact with the system, it allows the user to feed-in his decisions and entries need for the evaluation process, also after the evaluation the browser displays the results and rankings to the user
- ***Bootstrap*:** Most people are using multiple devices and they require a similar involvement in all the devices. Web pages have to be perfect to ensure the similar experience (Cletus, Kakandar and Paul, 2017). Statista Portal (https://www.statista.com/topics/779/mobile-internet/, Retrieved 20, December, 2017) stated that about 49.7% of websites access is via cell phones. Moreover, users spend more time on cell phones and tablets than on desktops (Shahibi and Aziz, 2017). Conventional websites are not planning to modify the page arrangements to various screen sizes and resolutions. This restriction of the conventional sites can evoke the loss of potential customers (Cletus, Kakandar and Paul, 2017). This means that developers should consider different resolutions during the application design. This is how Responsive Web Design (RWD) arises. It is a design that responds to any screen size, platform, and resolution. As the client changes from device to another, the site will normally change to the resolution of that specific device (Mikkonen, Systa and Pautasso, 2015). RWD is a procedure in which designers use media quires like HTML5, JavaScript, and CSS to control and pass on content that consequently changes on all screens, resolutions, and devices. RWD also empowers clients and site's proprietors to have the best user experience. Therefore, there is several RWD framework in the market today to help starters and experts develop brilliant websites (Amatya and Kurti, 2014).

  Bootstrap is one of the champion frameworks which was produced at Twitter in 2010. It is very much used by many well-known websites. Bootstrap contains libraries like CSS, fonts, and JavaScript which are all accessible for download. Bootstrap supports almost all web browsers like Chrome, Safari, Firefox, Opera and IE8-11, it can also work on 4 different platforms; Android, iOS, Mac OS X and

Windows (Voutilainen, Salonen and Mikkonen, 2015). Bootstrap gives styling to almost every component that a web application or site will require, it additionally offers sufficient documentation with examples and demos which make it very easy to use for a beginner. Bootstrap likewise has huge help groups that can help the user have issues. Moreover, bootstrap itself is always being updated and provides many themes.

- ***Asp.Net MVC*:** This is an open source framework developed by Microsoft for the development of modern web applications that can run on mac, window and Linux operating systems. It implements the Model-View- Controller pattern, which is the division of the application into three interconnected parts, i.e. model means how the data is maintained, view means how the data is displayed and controller means how the data is manipulated.
- ***C#*:** This is a programming language developed by Microsoft within the .Net framework. It was used here to code the Asp.net web application.
- ***IIS Express Server*:** Internet Information Services is an extensive web server which holds only the http and https protocols. It saves its settings based on user basis and does not need administrative rights and tries to avoid colliding with present web servers running on the same system. It handles asp.net requests by turning a computer into a web server that can provide web publishing services
- ***DEMATEL*:** This is a MCDM technique that was used in the developed system to assign weights to criteria
- ***TOPSIS*:** This MCDM technique was used by the system to rank the alternatives, and determine the best choice.
- ***Fuzzy Logic:*** The values in the DEMATEL technique ware converted to fuzzy logic in Triangular Fuzzy Number, and then deffuzified back to crisp values using best non fuzzy performance method.

B- LMS evaluation flowchart

This is the set of whole steps followed in the developed system for the LMS evaluation. The attributes are called criteria, the evaluation components are called the alternatives which participated in the evaluation process. Figure 4.4 shows the flowchart of the developed application.

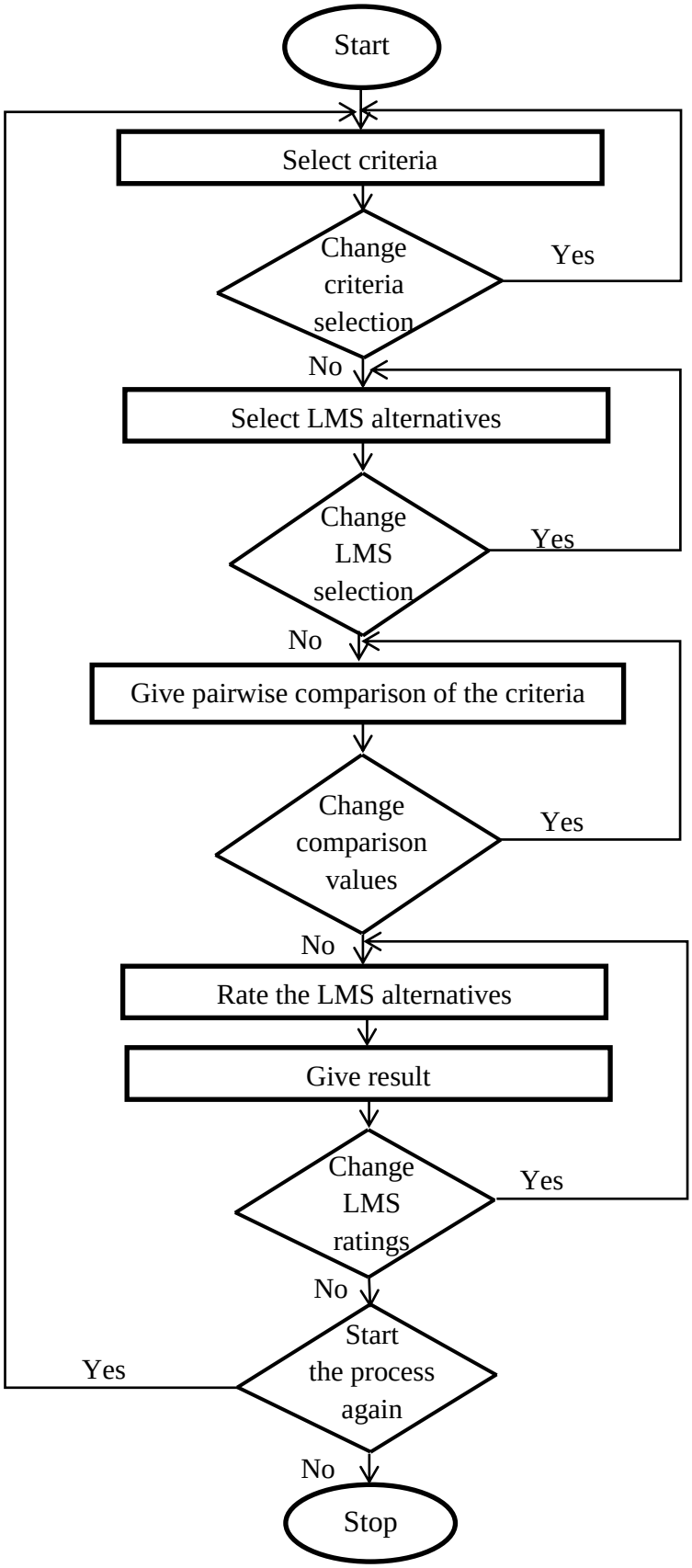

Figure 4.4: LMS evaluation flowchart of the developed system

C- Use case diagram

Use Case Diagrams are used to give a pictorial representation of the functionalities that can be performed while using a particular system from the users' perspective. Use Case Diagrams usually show the interaction between user and system. Each use case shown describes a task that the user can carry out effectively on the application.

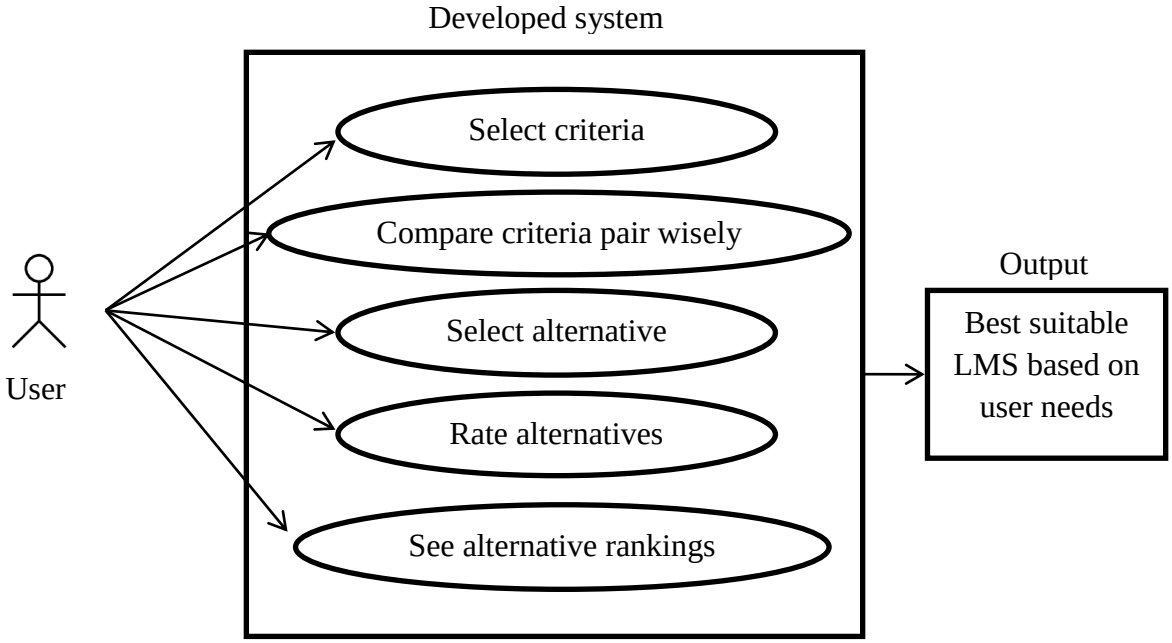

Figure 4.5: Use case diagram of the developed system

The use case diagram above depicts the functionalities that the user of the proposed application can carry out while using the application. Each use case in the diagram represents a unique functionality, which the user will be able to execute when using the application.

4.1.3 Implementation

This is the stage where the real programming and coding is performed. During the application development, the application programs, frameworks and programming languages used are as itemized below:

Programming Languages:

These are the programming languages, Integrated Development Environment (IDE), and platforms that have been used for the system development:

- Microsoft Visual Studio .NET 2017
  - Visual C# .NET
  - ASP .NET MVC
- Bootstrap
  - Hyper Text Mark-up Language (HTML)
  - Cascading Style Sheets
- Javascript

4.1.4 Testing

This is the stage where the whole system is been tested for its design, functionality, and usability. The system was tested by 6 computer experts and then give the following responds and suggestions.

- The color combination of the user interface should be changed.
- The system should be responsive i.e. it should be able to run on all devices.
- Brief explanation on what a user is expected to do should be given at each stage.

4.1.5 Maintenance

This stage is attained when the system is hosted or installed and started to be used. Maintenance includes debugging errors that have not been identified in previous stages of the SDLC, analyse if a new requirement is found, then follow the steps again from the stage that needs to be improved.

4.2 Research Schedules

This study was conducted from September 2017 to December 2017. Figure 4.6 describes each task and the duration it takes during the research, while and Figure 4.7 is the Gantt chart for the thesis.

Task Name	Duration	Start	Finish
Full thesis schedule	**110 days**	**Tue 08/08/17**	**Mon 08/01/18**
Identifying the research area	7 days	Tue 08/08/17	Wed 16/08/17
Related research	17 days	Thu 17/08/17	Fri 08/09/17
Thesis proposal	**10 days**	**Fri 08/09/17**	**Thu 21/09/17**
Writing thesis proposal	5 days	Fri 08/09/17	Thu 14/09/17
Proposal review	3 days	Fri 15/09/17	Tue 19/09/17
Thesis approval	2 days	Wed 20/09/17	Thu 21/09/17
Documentations	**50 days**	**Wed 20/09/17**	**Tue 28/11/17**
Writing thesis	25 days	Wed 20/09/17	Tue 24/10/17
Thesis review	15 days	Wed 25/10/17	Tue 14/11/17
Final thesis draft	10 days	Wed 15/11/17	Tue 28/11/17
System development	**46 days**	**Tue 24/10/17**	**Tue 26/12/17**
Analysis	7 days	Tue 24/10/17	Wed 01/11/17
Design	10 days	Thu 02/11/17	Wed 15/11/17
Implementation	18 days	Thu 16/11/17	Mon 11/12/17
Testing	7 days	Tue 12/12/17	Wed 20/12/17
Maintenance	4 days	Thu 21/12/17	Tue 26/12/17
Last revision of the thesis	**7 days**	Fri 29/12/17	Mon 08/01/18

Figure 4.6: Research schedule of the study

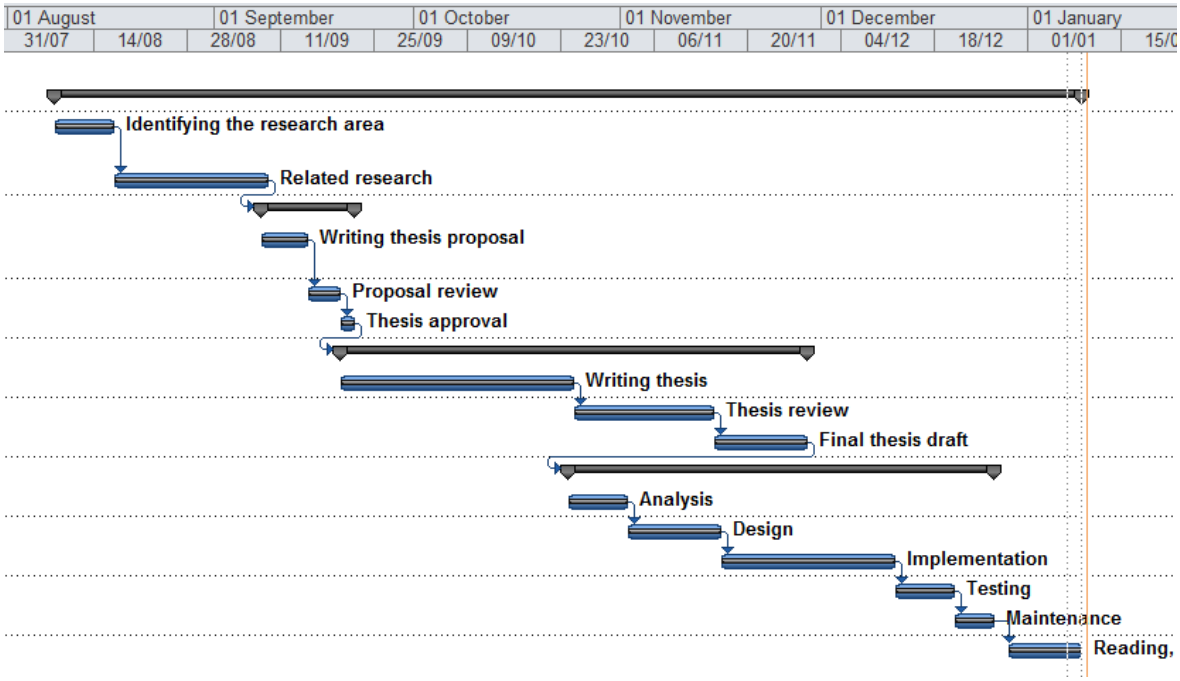

Figure 4.7: Gantt chart of the study

CHAPTER 5

IMPLEMENTATION: CASE STUDY OF THE DEVELOPED SYSTEM

This chapter is the system implementation section, it gives the full description of how the system works to achieve the LMS evaluation, it start from the criteria selection to the result section which is the LMS alternative ranking. At each stage, a screen capture is given to show how it appears on the system.

5.1 Case Study

The step by step evaluation process of the developed system is shown here. The screen capture of each step from the system in mobile view is shown with brief information. Figure 4.8 shows the home page of the developed system.

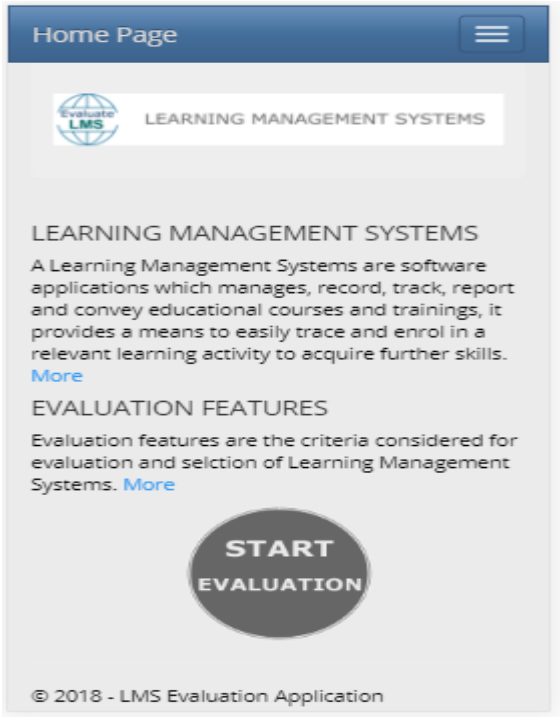

Figure 4.8: Home page

Step 1: Choosing LMS Criteria

Figure 4.6 below is the criteria selection page which is the first step for the LMS evaluation. It shows the list of all 24 criteria. The user can choose the group of criteria by clicking on the check boxes near each criteria name, the user is expected to choose at least 2 criteria for the system to be able to start the evaluation.

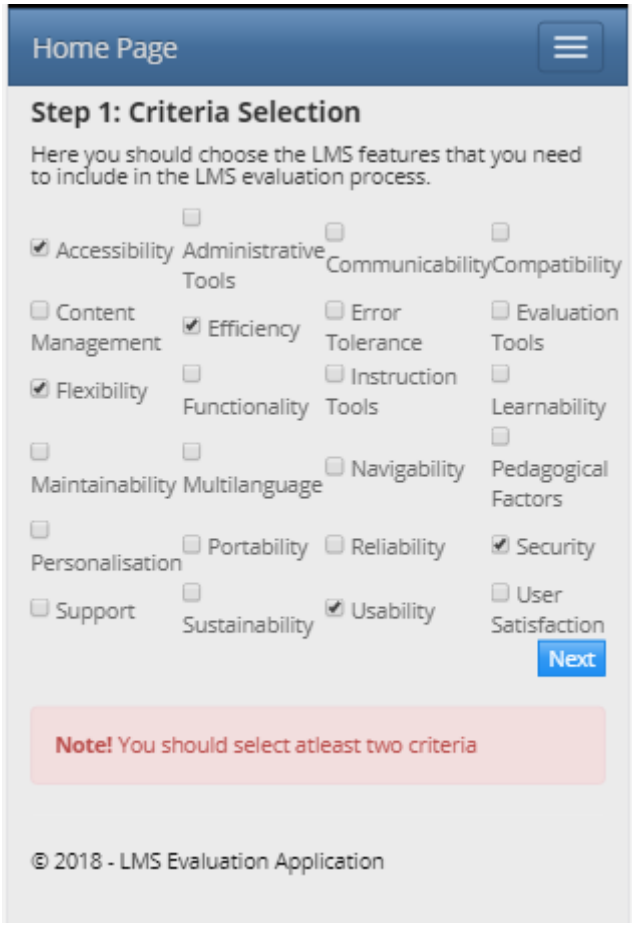

Figure 4.9: Criteria selection page

In this case, 5 evaluation criteria are selected, and they are accessibility, efficiency, flexibility, security and usability.

Step 2: Choosing the LMS alternatives

This is the second step for the LMS evaluation, it is the page where thee user will choose the alternatives that he needs to include in the evaluation process, the user is also required to choose at least 2 alternatives for the system to start the evaluation.

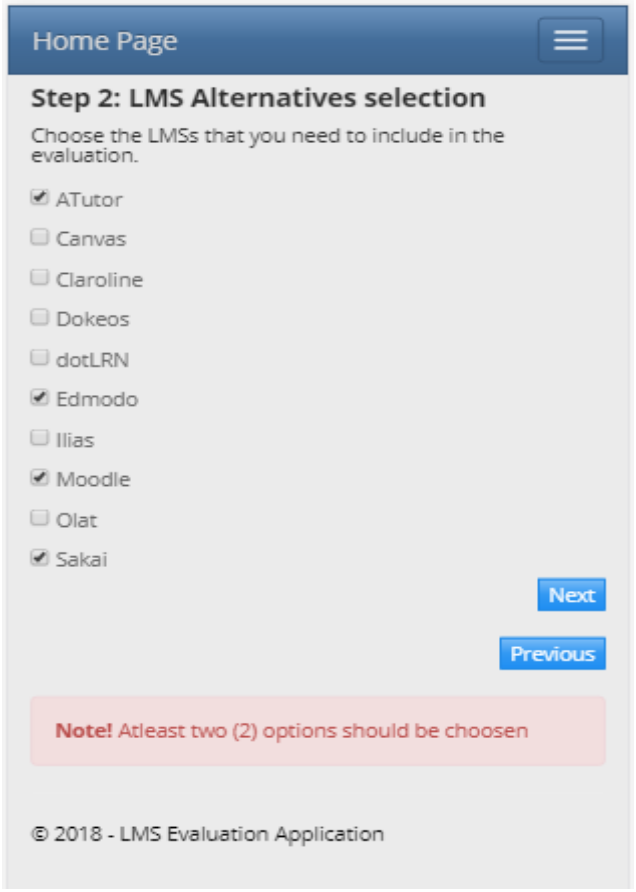

Figure 4.10: LMS alternative selection page

In this case study, 4 LMS alternatives are selected, they are: ATutor, Edmodo, Moodle, and Sakai.

Step 3: Pairwise comparison of criteria

This is the third step of the LMS evaluation. The user is expected to give a pairwise comparison of the criteria he selected i.e. in his opinion, how does the criteria affect each other. A scale of 5 values will be used for the comparison; No influence (No), Very low influence (VLI), Low influence (LI), High influence (HI) and Very high influence (VHI). If a user did not choose any value, then a default value; No influence (No) will be selected.

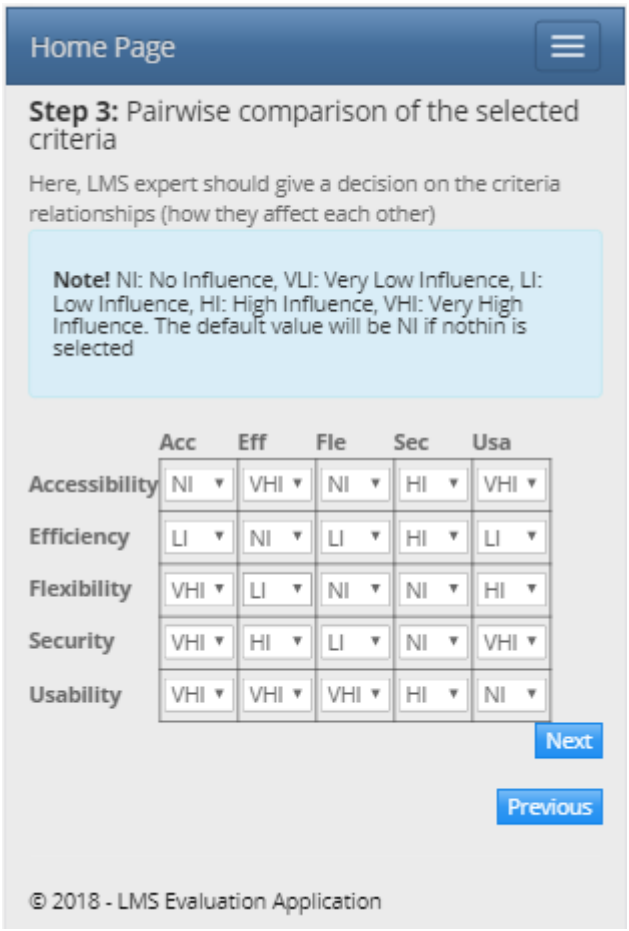

Figure 4.11: Criteria pairwise comparison page

Step 4: Alternatives rating

This is the fourth step for the LMS evaluation. A user is expected to rate each alternative he choosed based on each criteria in his opinion. A 5 point scale is also used for the rating; Very poor (VP), Poor (P), Medium (M), Good (G) and Very good (VG). If a user did not choose any value, then the default value will be Very poor (VP).

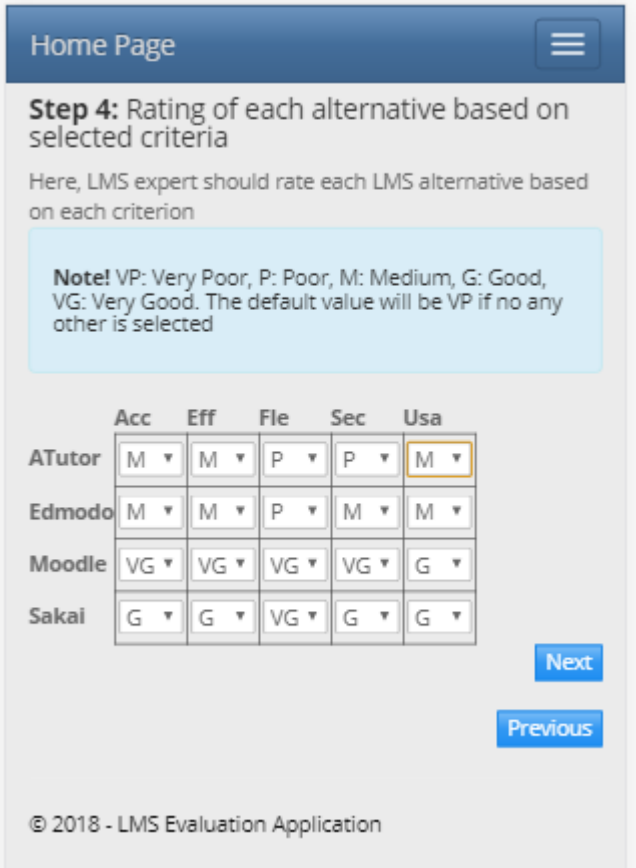

Figure 4.12: LMS alternatives rating page

Step 5: Result

This is the final step and result section for the LMS evaluation based on the selected set of criteria and alternative. The alternatives that participated in the evaluation are listed based on their rankings. The best suitable LMS alternative is the first then the rest follows.

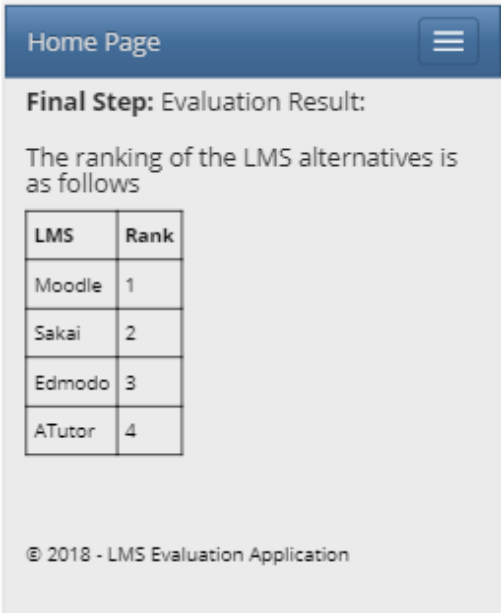

Figure 4.13: Evaluation result

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

This chapter gives the conclusion, recommendations and suggestions for further research in this area of study.

6.1 Conclusion

Because of the huge amount of e-learning systems; LMSs offered yearly over the web and because of this rapid development in educational technologies over the world. There is no doubt that we need some tools to evaluate the quality, efficiency, and performance of the LMSs. But the manual selection of LMSs had resulted many individuals in making selection prematurely. So a developed system will be of great important here in order to ease and make the selection more efficient and effective. This study is a development of a web based system which combined two methods fuzzy DEMATEL and TOPSIS to weight and ranks LMS alternatives respectively in order to make a more reliable selection within a short stipulated time. The features are selected which determine the framework that will be used for the evaluation process. The empirical study showed that "*Moodle*" LMS was ranked as the best LMS choice with regards solely to this study. For this study, the researcher acted as the decision maker. This developed system will help LMS evaluation much easier, faster and cost effective. It will help educational institutions, organisations and individuals in selecting the most suitable and efficient LMS based on their individual needs.

6.2 Recommendations

For future related study, this method can further be integrated with other MCDM methods like the fuzzy ANP to improve the selection and evaluation process of the LMSs. In addition, the number of criteria and the LMSs alternatives should also be increased and different languages should be included to the application interface.

In future studies, it is recommended that the criteria list and the LMS alternative list should be added to the system or removed by a user. It as also recommended that in the user interface design, a selectall checkbox should be added inorder to select or deselect all features or LMS alternatives at the same time.

REFERENCES

Abdullateef, B. N., Elias, N. F., Mohamed, H., Zaidan, A. A., and Zaidan, B. B. (2015). Study on open source learning management systems: a survey, profile, and taxonomy. *Journal of Theoretical and Applied Information Technology*, *82*(1), 93.

Aberdour, M. (2007). Open source learning management systems. Epic.

Akyuz, E., and Celik, E. (2015). A fuzzy DEMATEL method to evaluate critical operational hazards during gas freeing process in crude oil tankers. *Journal of Loss Prevention in the Process Industries*, *38*, 243-253.

Al-Ajlan, A., and Zedan, H. (2008). Why Moodle. *In Proceedings of the 12th International Workshop on Future Trends of Distributed Computing Systems* (pp. 58-64). Kunming, China.

Alam-Tabriz, A., Rajabani, N., and Farrokh, M. (2014). An integrated fuzzy DEMATEL-ANP-TOPSIS methodology for supplier selection problem. *Global Journal of Management Studies and Researches*, *1*(2), 85-99.

Albarrak, A. I., Aboalsamh, H. A., and Abouzahra, M. (2010). Evaluating learning management systems for university medical education. *In Proceedings of the International Conference on Education and Management Technology* (pp. 672-677). Cairo, Egypt.

Alharthi, A. D., and Spichkova, M. (2017). Individual and social requirement aspects of sustainable elearning systems. *In Proceedings of the International Conference on Engineering Education and Research* (pp 1-8). Sydney, Australia.

Amatya, S., and Kurti, A. (2014). Cross-platform mobile development: challenges and opportunities. *In Proceedings of the ICT Innovations* (pp. 219-229). Ohrid, Macedonia.

Amir, E. S., Sumadyo, M., Sensuse, D. I., Sucahyo, Y. G., and Santoso, H. B. (2016). Automatic detection of learning styles in learning management system by using literature-based method and support vector machine. *In Proceedings of the International Conference on Advanced Computer Science and Information Systems* (pp. 141-144). Ancol, Jakarta

Anggrainingsih, R., Johannanda, B. O. P., Kuswara, A. P., Wahyuningsih, D., and Rejekiningsih, T. (2016). Comparison of maintainability and flexibility on open source LMS. *In Proceedings of the International Seminar on Application for Technology of Information and Communication* (pp. 273-277). Semarang, Indonesia

Arh, T., and Blazic, B. J. (2007). A multi-attribute decision support model for learning management systems evaluation. *In Proceedings of the Digital Society, First International Conference* (pp. 11-15). Guadeloupe, France

Attia, M., Abdel-Fattah, M. A., and El-Gaber, S. A. (2016). A Model for Assessing and Enhancing Efficiency of E-learning systems. *International Journal of Computer Applications*, *156*(6).

Awang, N. B., and Darus, M. Y. B. (2012). Evaluation of an open source learning management system: Claroline. *Procedia-Social and Behavioral Sciences*, *67*, 416-426.

Babic, F., Wagner, J., Jadlovská, S., and Lesko, P. (2010). A logging mechanism for acquisition of real data from different collaborative systems for analytical purposes. *In Proceedings of the 8th International Symposium on Applied Machine Intelligence and Informatics* (pp. 109-112). Herlany, Slovakia

Bagozzi, R. P., and Dholakia, U. M. (2006). Open source software user communities: A study of participation in Linux user groups. *Management Science*, *52*(7), 1099-1115.

Balaji, S., and Murugaiyan, M. S. (2012). Waterfall vs. v-model vs. agile: a comparative study on SDLC. *International Journal of Information Technology and Business Management*, 2(1), 26-30.

Barjtya, S., Sharma, A., and Rani, U. (2017) A detailed study of Software Development Life Cycle (SDLC) models. *International Journal of Engineering and Computer Science* , *6*(7), 22097-22100.

Bassil, Y. (2012). A simulation model for the waterfall software development life cycle. *International Journal of Engineering & Technology, 2*(5), 2049-3444.

Baykasoglu, A. and Golcuk, I. (2017). Development of an interval type-2 fuzzy sets based hierarchical MADM model by combining DEMATEL and TOPSIS. *Expert Systems with Applications, 70,* 37-51.

Bayon, A., Santos, O. C., and Boticario, J. G. (2008). A component to carry out the Logical Framework Approach in dotLRN. *In Proceedings of the 7th OpenACS/. LRN conference* (pp. 1-8). Valencia, Spain.

Bhatnagar, S., Dubey, S. K., and Rana, A. (2012). Quantifying website usability using fuzzy approach. *International Journal of Soft Computing and Engineering*, *2*(2), 424-428.

Caminero, A. C., Hernandez, R., Ros, S., Robles-Gomez, A., and Tobarra, L. (2013). Choosing the right LMS: A performance evaluation of three open-source LMS. *In Proceedings of the Global Engineering Education Conference* (pp. 287-294). Berlin, Germany.

Cavus, N. (2007). HYPERLINK "http://docs.neu.edu.tr/library/4956059057.pdf" \t "_blank" The effects of using learning management systems on collaborative learning for teaching programming languages. *Dissertation, Near East University, Graduate School of Applied Sciences, Department of Computer Information Systems*, Nicosia, Cyprus.

Cavus, N. (2013). Selecting a learning management system (LMS) in developing countries: instructors' evaluation. *Interactive Learning Environments, 21*(5), 419-437.

Cavus, N. (2015). Distance Learning and Learning Management Systems. *Procedia-Social and Behavioral Sciences, 191,* 872-877.

Cavus, N., and Alhih, M. S. (2014). Learning management systems use in science education. *Procedia-Social and Behavioral Sciences, 143,* 517-520.

Cavus, N., and Zabadi, T. (2014). A comparison of open source learning management systems. *Procedia-Social and Behavioral Sciences, 143,* 521-526.

Cavus, N., Uzunboylu, H., and Ibrahim, D. (2006). The effectiveness of using learning management systems and collaborative tool in web-based teaching of programming languages. *In proceedings of the International Symposium and Education on Electrical, Electronic, and Computer Engineering*. Lefkoşa, Cyprus.

Cetin, A., Isık, A. H., and Guler, I. (2010). Learning management system selection with analytic hierarchy process. *In Proceedings of the 13th International Conference on Interactive Computer Aided Learning* (pp. 921-926). Hasselt, Belgium.

Chang, B., Chang, C. W., and Wu, C. H. (2011). Fuzzy DEMATEL method for developing supplier selection criteria. *Expert Systems with Applications*, *38*(3), 1850-1858.

Chang, K. (2014). Integrating TOPSIS and DEMATEL methods to rank the risk of failure of FMEA. *International Journal of Information Technology and Decision Making, 13,* 1-29.

Chen, J., and Yang, Y. (2011). A fuzzy ANP-based approach to evaluate region agricultural drought risk. *Procedia Engineering, 23,* 822-827.

Cletus, W. D., Kakandar, A., and Paul, C. N. (2017). Responsive web design frameworks: A review. *International Journal of Scientific Research in Computer Science, Engineering and Information Technology, 2*(5), 2456-3307.

Dalalah, D. Hayajneh, M., and Batieha, F. (2011). A fuzzy multi criteria decision making model for supplier selection. *Expert Systems with Applications, 38,* 8384-8391.

Dalalah, D. (2009). A Hybrid DEMATEL-TOPSIS multi criteria decision making model. *In Proceedings of the International Conference on Information Reuse and Integration,* (pp 428 - 430). Las Vegas, NV, USA.

Dalalah, D., Hayajneh, M., and Batieha, F. (2011). A fuzzy multi criteria decision making model for supplier selection. *Expert Systems with Applications*, *38*(7), 8384-8391.

Dargi, A., Anjomshoae, A., Galankashi, M. R., Memari, A., and Tap, M. B. M. (2014). Supplier selection: A fuzzy-ANP approach. *Procedia Computer Science*, *31*, 691-700.

Debnath, A., Majumder, M., and Pal, M. (2016). Potential of Fuzzy-ELECTRE MCDM in evaluation of cyanobacterial toxins removal methods. *Arabian Journal for Science and Engineering*, *41*(10), 3931-3944.

Docebe (2014). E-Learning Market Trends and Forecast 2014 - 2016 Report. Retrieved November 13, 2017 from https://www.docebo.com/landing/contactform/elearning-market-trends-and-forecast-2014-2016-docebo-report.pdf.

Dursun, M., and Arslan, O. (2016). A Fuzzy MCDM approach to determine critical evaluation criteria in washing liquid material selection procedure. *In Proceedings of the World Congress on Engineering* (pp. 1-5). London, U.K.

EasyLMS (2017). History of LMS. Retrieved December 20, 2017 from HYPERLINK "https://www.easy-lms.com/help/lms-knowledge-center/history-of-lms/item10401" https://www.easy-lms.com/help/lms-knowledge-center/history-of-lms/item10401 .

Edmodo (2017). About Edmodo. Retrieved December 20, 2017 from HYPERLINK "https://www.edmodo.com/about" https://www.edmodo.com/about .

Edrees, M. E. (2013). eLearning 2.0: Elearning 2.0: Learning management systems readiness. *In Proceedings of the Fourth International Conference on* e-*Learning "Best Practices in Management, Design and Development of e-Courses: Standards of Excellence and Creativity"* (pp. 90-96). Manama, Bahrain.

Education Technology (2017). Free & Open Source Learning Management Systems. Retrieved December 20, 2017 from HYPERLINK "https://educationaltechnology.net/free-open-source-learning-management-systems/" https://educationaltechnology.net/free-open-source-learning-management-systems/ .

El Tantawi, M. M., Abdelsalam, M. M., Mourady, A. M., and Elrifae, I. M. (2015). e-Assessment in a limited-resources dental school using an open-source learning management system. *Journal of dental education*, *79*(5), 571-583.

Elabnody, M. R. (2015). A Survey of top 10 open source learning management systems. *International Journal of Scientific & Technology Research*, *4*(8), 7-11.

E-logic Learning. (2017). 15 ELearning Trends and Statistics to Know for 2017. Retrieved 22, October, 2017 from https://elogiclearning.com/15-elearning-trends-and-statistics-to-know-for-2017.

Ergu, D., Kou, G., Shi, Y., and Shi, Y. (2014). Analytic network process in risk assessment and decision analysis. *Computers and Operations Research*, *42*, 58-74.

Ferrara, E., Ponte, S., Caputo, E., Frascio, M., and Dellepiane, S. (2016). Sustainable cooperative distance learning system for education in developing countries. In the proceedings of *IST-Africa Week Conference, 2016* (pp. 1-8). Durban, South Africa.

Fidalgo-Blanco, Á., García-Peñalvo, F. J., Sein-Echaluce, M. L., and Conde-González, M. Á. (2014). Learning content management systems for the definition of adaptive

learning environments. *In the proceedings of the International Symposium on Computers in Education* (pp. 105-110). Logrono, Spain.

Fosfuri, A., Giarratana, M. S., and Luzzi, A. (2008). The penguin has entered the building: The commercialization of open source software products. *Organization Science*, *19*(2), 292-305.

Ghapanchi, A. H. (2014). Investigating the Success of OSS Software Projects. *Human Factors in Software Development and Design*, Hershey, PA, USA: IGI Publishing.

Gupta, D., Ahlawat, A. K., and Sagar, K. (2017). Usability prediction and ranking of SDLC models using fuzzy hierarchical usability model. *Open Engineering*, *7*(1), 161-168.

Gurunath, R., and Kumar, R. A. (2015). SAAS explosion leading to a new phase of a learning management system. *International Journal of Current Research and Review*, *7*(22), 62.

Hock, S. Y., Omar, R., and Mahmud, M. (2015). Comparing the usability and users acceptance of open sources Learning Management System (LMS). *International Journal of Scientific and Research Publications*, *5*(4), 1-5.

Hung, S. J. (2011). Activity-based divergent supply chain planning for competitive advantage in the risky global environment: A DEMATEL-ANP fuzzy goal programming approach. *Expert Systems with Applications*, *38*(8), 9053-9062.

Isik, A.H., Ince, M., and Yigit, T. (2015). A Fuzzy AHP Approach to select learning management system. *International Journal of Computer Theory and Engineering*, *7*(6), 499.

Karagoz, E., Oral, L. O., Kaya, O. H., and Tecim, V. (2017). LMS selection process for effective distance education system in organizations. *KnE Social Sciences*, *1*(2), 343-356.

Kashi, K. (2015). DEMATEL method in practice: finding the causal relations among key competencies. *In Proceedings of the 9th International Days of Statistics and Economics* (pp.723-732). Prague.

Keleş, M. K., and Ozel, S. A. (2016). Virtual Learning. In D. Cvetković (Ed), *A review of distance learning and learning management systems* (pp. 1-19). InTech.

Khaimook, K. (2010). Multilingual Learning Management System (MLMS). *In Proceedings of the Society for Information Technology & Teacher Education International Conference* (pp. 2472-2475). San Diego, USA.

Khan, F. A., Shahzad, F., and Altaf, M. (2017). Fuzzy based approach for adaptivity evaluation of web based open source Learning Management Systems. *Cluster Computing*, 1-11.

Kiris, S. (2013). Multi-criteria inventory classification by using a fuzzy analytic network process (ANP) approach. *Informatica*, *24*(2), 199-217.

Krishnamurthy, S., Ou, S., and Tripathi, A. K. (2014). Acceptance of monetary rewards in open source software development. *Research Policy*, *43*(4), 632-644.

Kumar, V., and Sharma, D. (2016). Creating Collaborative and Convenient Learning Environment Using Cloud-Based Moodle LMS: An Instructor and Administrator Perspective. *International Journal of Web-Based Learning and Teaching Technologies, 11*(1), 35-50.

Kuran, M. Ş., Pedersen, J. M., and Elsner, R. (2017). Learning Management Systems on Blended Learning Courses: An Experience-Based Observation. *In the proceedings of the International Conference on Image Processing and Communications* (pp. 141-148). Bydgoszcz, Poland.

LearnDash (2015). History of the LMS. Retrieved December 20, 2017 from HYPERLINK "https://www.learndash.com/history-of-the-lms/" https://www.learndash.com/history-of-the-lms/ .

Lee, D. H., Shon, J. G., and Kim, Y. (2015). Design and implementation of OSMD based learning management system for mobile learning. *Indian Journal of Science and Technology*, *8*(S1), 154-160.

Lin, C. J., and Wu, W. W. (2008). A causal analytical method for group decision-making under fuzzy environment. *Expert Systems with Applications*, *34*(1), 205-213.

Lin, L. Z., and Hsu, T. H. (2011). Designing a model of FANP in brand image decision-making. *Applied Soft Computing*, *11*(1), 561-573.

Lin, R. J. (2013). Using fuzzy DEMATEL to evaluate the green supply chain management practices. *Journal of Cleaner Production*, *40*, 32-39.

Macfadyen, L. P., and Dawson, S. (2010). Mining LMS data to develop an "early warning system" for educators: A proof of concept. *Computers & Education*, *54*(2), 588-599.

Machado, M., and Tao, E. (2007, October). Blackboard vs. Moodle: Comparing user experience of learning management systems. *In Proceeding of the 37th Annual Frontiers In Education Conference-Global Engineering: Knowledge without Borders, Opportunities without Passports,* (pp. S4J-7). Milwaukee, WIsconsin, USA.

Maiti, A., Maxwell, A. D., Kist, A. A., and Orwin, L. (2014). Integrating enquiry-based learning pedagogies and remote access laboratory for STEM education. *In the proceedings of the Global Engineering Education Conference* (pp. 706-712). Istanbul, Turkey.

Malone, D. (2015). Using Synchronous Video Within a Learning Management System for Library and Information Literacy Instruction. *Public Services Quarterly, 11*(3), 208-216.

McKenna, G. F., Baxter, G. J., and Hainey, T. (2016). Applying e-portfolio evaluation criteria to the blackboard LMS e-portfolio. In proceedings of the *Utilizing Virtual and Personal Learning Environments for Optimal Learning* (pp. 157-185).

Medina-Flores, R., and Morales-Gamboa, R. (2015). Usability evaluation by experts of a learning management system. *Revista Iberoamericana de Tecnologias del Aprendizaje, 10*(4), 197-203.

Mehta, P., and Saroha, K. (2016). Analysis and evaluation of learning management system using data mining techniques. *In Proceedings of the Fifth International Conference on Recent Trends in Information Technology* (pp. 1-5). Chennai, India.

Mikkonen, T., Systä, K., and Pautasso, C. (2015). Towards liquid web applications. *In Proceedings of the International Conference on Web Engineering* (pp. 134-143).

Mindflash (2107). History of the LMS. Retrieved December 20, 2017 from HYPERLINK "https://www.mindflash.com/learning-management-systems/history-of-lms" https://www.mindflash.com/learning-management-systems/history-of-lms .

Modi, H. S., Singh, N. K., and Chauhan, H. P. (2017). Comprehensive analysis of software development life cycle models. *International Research Journal of Engineering and Technology, 4*(6), 117-122.

Mohammadi, H., Nouri, I., and Ehsanifar, M. (2013). Applying fuzzy DEMATEL method to analyse supplier selection criteria (case study: wagonpars company). *International Research Journal of Finance and Economics*, *115*, 76-86.

Muhammad, M. N., and Cavus, N. (2017a). Quality evaluation of learning management systems using DEMATEL-ANP. *In Proceedings of the 11th International Technology, Education and Development Conference* (pp. 5754-5760). Valencia, Spain.

Muhammad, M. N., and Cavus, N. (2017b). Fuzzy DEMATEL method for identifying LMS evaluation criteria. *Procedia Computer Science*, *120*, 742-749.

Natarajan, M. (2015). Evaluation methods for e-learning: an analytical study. *International Journal of Library and Information Science*, *1*(1), 1-14.

Nazeri, A., and Naderikia, R. (2017). A new fuzzy approach to identify the critical risk factors in maintenance management. *The International Journal of Advanced Manufacturing Technology*, *92*(9-12), 3749–3783.

Nicholas, C. (2017). Establishing and Maintaining a Dynamic Learning & Teaching Community via an Online Learning Management System Platform. *Ergo*, *3*(4).

Novakovich, J. (2016). Fostering critical thinking and reflection through blog-mediated peer feedback. *Journal of Computer Assisted Learning*, *32*(1), 16-30.

Oh, S., Kim, G., Jung, Y., Kim, D., and Kim, H. S. (2015). Risk assessment of heavy snowfall using PROMETHEE-The Case of Gangwon Province. *Journal of Korean Society of Hazard Mitigation*, *15*(1), 87-98.

Ortiz, M. A., Felizzola, H. A., and Isaza, S. N. (2015). A contrast between DEMATEL-ANP and ANP methods for six sigma project selection: a case study in healthcare industry. *BMC Medical Informatics and Decision Making*, *15*(3), 1-12.

Osterloh, M., and Rota, S. (2007). Open source software development—Just another case of collective invention?. *Research Policy*, *36*(2), 157-171.

Padayachee, I., Kotze, P., and van Der Merwe, A. (2010). ISO 9126 external systems quality characteristics, sub-characteristics and domain specific criteria for evaluating e-Learning systems. *The Southern African Computer Lecturers' Association*, South Africa.

Pathinathan, T., and Ponnivalavan, K. (2015). Reverse order triangular, trapezoidal and pentagonal fuzzy numbers. *Annals of Pure and Applied Mathematics*, *9*(1), 107-117.

Paz, F., and Pow-Sang, J. A. (2016). A systematic mapping review of usability evaluation methods for software development process. *International Journal of Software Engineering and its Applications*, *10*(1), 165-178.

Peraza, J., Estrada-Lizarraga, R., Zaldívar-Colado, A., Mendoza-Zatarain, R., Olivarría, M., and Cobián, J. (2012). Importance of implementing optimal learning management systems for e-learning in higher education. *In Proceedings of the international Conference of Education, Research and Innovation* (pp. 530-535). Madrid, Spain.

Piña, A. A. (2018). An Educational Leader's View of Learning Management Systems. *In proceedings of the Leading and Managing e-Learning* (pp. 101-113).

Powell, A. (2016). An Overview of K-12 Digital Content in North America. *In proceedings of the ICT in Education in Global Context* (pp. 123-141). Berlin Heidelberg.

Pretorius, M., and van Biljon, J. (2010). Learning management systems: ICT skills, usability and learnability. *Interactive Technology and Smart Education*, *7*(1), 30-43.

Radwan, N., Senousy, M. B., Riad, M., and El Din, A. (2016). A new expert system for learning management systems evaluation based on neutrosophic sets. *Expert Systems*, *33*(6), 548-558.

Rafi, A., Samsudin, K., and Hanafi, H. F. (2015). E-Learning-Instructional Design, Organizational Strategy and Management. In B. Gradinarova (Ed), *Differences in perceived benefit, use, and learner satisfaction between open source LMS and proprietary LMS* (pp. 363-378). InTech.

Ramesh, V. M. and Ramanathan, C. (2013). A rubric to evaluate learning management systems. *In Proceedings of the International Conference on Teaching, Assessment and Learning for Engineering* (pp. 73-77). Bali, Indonesia.

Ramos, P. R. H., Peñalvo, F. J. G., & González, M. Á. C. (2014, October). Towards mobile personal learning environments (MPLE) in higher education. *In Proceedings of the Second International Conference on Technological Ecosystems for Enhancing Multiculturality* (pp. 677-681).

Rouyendegh, B. D., and Erkan, T. E. (2013). An application of the fuzzy electre method for academic staff selection. *Human Factors and Ergonomics in Manufacturing and Service Industries*, *23*(2), 107-115.

Saaty, T. L. (2004). Fundamentals of the analytic network process—dependence and feedback in decision-making with a single network. *Journal of Systems science and Systems engineering*, *13*(2), 129-157.

Sakai (2017). About Sakai. Retrieved December 20, 2017 from HYPERLINK "https://www.sakaiproject.org/about" https://www.sakaiproject.org/about .

Sangaiah, A. K., Subramaniam, P. R., and Zheng, X. (2015). A combined fuzzy DEMATEL and fuzzy TOPSIS approach for evaluating GSD project outcome factors. *Neural Computer and Applications, 26,* 1025–1040.

Sanna, P. S., & Marcialis, G. L. (2017, September). Remote Biometric Verification for eLearning Applications: Where We Are. *In Proceedings of the International Conference on Image Analysis and Processing* (pp. 373-383).

Satty, T. L. (1996). The Analytic Network Process. RWS Publication.

Sedivy, J. (2011). Creation of multimedia support study material and administration of LMS systems in virtual education environment. *In Proceedings on the International Conference on Interactive Collaborative Learning* (pp. 477-479). Piestany, Slovakia.

Sen, D. K., Datta, S., Patel, S. K., and Mahapatra, S. S. (2015). Multi-criteria decision making towards selection of industrial robot: exploration of PROMETHEE II method. *Benchmarking: An International Journal*, *22*(3), 465-487.

Shahibi, M. S., and Aziz, F. A. (2017). The Effect of smartphone that influence the compulsive usage among students. *International Journal of Academic Research in Business and Social Sciences*, *7*(8), 888-908.

Shieh, J. I., Wu, H. H., and Huang, K. K. (2010). A DEMATEL method in identifying key success factors of hospital service quality. *Knowledge-Based Systems*, *23*(3), 277-282.

Silva, J. M. C. (2014). How Can the Affective Model be for Tutors on Moodle?. In the proceedings of the 12th Annual Conference on Intelligent Tutoring Systems (pp 34-39). Honolulu, HI.

Srdevic, B., Pipan, M., Srdevic, Z., and Arh, T. (2012). AHP supported evaluation of lms quality. *In Proceedings of the International Workshop on the Interplay between*

User Experience Evaluation and Software Development (pp.52-57). Copenhagen, Denmark.

Stam, W. (2009). When does community participation enhance the performance of open source software companies?. *Research Policy*, *38*(8), 1288-1299.

Statista Portal (2017). Mobile Internet - Statistics & Facts. Retrieved December 20, 2017 from https://www.statista.com/topics/779/mobile-internet/.

Stuttard, D., and Pinto, M. (2011). *The web application hacker's handbook: finding and exploiting security flaws*. John Wiley and Sons.

Sumrit, D., and Anuntavoranich, P. (2013). Using DEMATEL method to analyze the causal relations on technological innovation capability evaluation factors in Thai technology-based firms. *International Transaction Journal of Engineering, Management, & Applied Sciences Technologies*, *4*(2), 081-103.

Synotive (2017). History of Learning Management System (LMS). Retrieved December 20, 2017 from HYPERLINK "https://www.synotive.com/blog/history-of-learning-management-system-lms" https://www.synotive.com/blog/history-of-learning-management-system-lms .

Taechatanasat, P., Armstrong, L., and Nilsook, P. (2016, December). Designing a multilanguage blended learning system for Thai agricultural science students. *In Proceedings of the International Conference on Teaching, Assessment, and Learning for Engineering* (pp. 131-138).

Thien, P. C., Le Van Phan, N. K. L., Tho, Q. T., Suhonen, J., and Sutinen, E. (2013). Applying Edmodo to serve an online distance learning system for undergraduate students in Nong Lam University. *In Proceedings of the International Engineering and Technical Education Conference*. Ho Chi Minh City, Vietnam.

Tsai, W. H., and Hsu, W. (2010). A novel hybrid model based on DEMATEL and ANP for selecting cost of quality model development. *Total Quality Management*, *21*(4), 439-456.

Tscheikner-Gratl, F., Egger, P., Rauch, W., and Kleidorfer, M. (2017). Comparison of multi-criteria decision support methods for integrated rehabilitation prioritization. *Water*, *9*(2), 68.

Tseng, ML. (2011). Using hybrid MCDM to evaluate the service quality expectation in linguistic preference. *Applied Soft Computing*, *11*, 4551-4562.

Tuzkaya, U. R., and Önüt, S. (2008). A fuzzy analytic network process based approach to transportation-mode selection between Turkey and Germany: A case study. *Information Sciences*, *178*(15), 3133-3146.

Tzeng, G. H., Chiang, C. H., and Li, C. W. (2007). Evaluating intertwined effects in e-learning programs: A novel hybrid MCDM model based on factor analysis and DEMATEL. *Expert systems with Applications*, *32*(4), 1028-1044.

Uygun, O., Kaçamak, H., and Kahraman, U. A. (2015). An integrated DEMATEL and fuzzy ANP techniques for evaluation and selection of outsourcing provider for a telecommunication company. *Computers and Industrial Engineering*, *86*, 137-146.

Vinodh, S., Balagi, T. S., and Patil, A. (2016). A hybrid MCDM approach for agile concept selection using fuzzy DEMATEL, fuzzy ANP and fuzzy TOPSIS. *The International Journal of Advanced Manufacturing Technology*, *83*(9-12), 1979-1987.

Visalakshmi, S. and Lakshmi, P. (2015) An integrated fuzzy DEMATEL-TOPSIS approach for financial performance evaluation of GREENEX industries. *International Journal of Operational Research*, *23*(3), 340-362.

Voutilainen, J. P., Salonen, J., and Mikkonen, T. (2015). On the design of a responsive user interface for a multi-device web service. *In Proceedings of the Second ACM International Conference on Mobile Software Engineering and Systems* (pp. 60-63).

Wharekura-Tini, H., and Aotearoa, K. (2004). Technical evaluation of selected learning management systems. *Master's thesis, Catalyst IT Limited, Open Polytechnic of New Zealand*.

Wu, W. W., and Lee, Y. T. (2007). Developing global managers' competencies using the fuzzy DEMATEL method. *Expert systems with Applications*, *32*(2), 499-507.

Xu, P., and Chan, E. H. (2013). ANP model for sustainable building energy efficiency retrofit using energy performance contracting for hotel buildings in China. *Habitat International*, *37*, 104-112.

Yang, J. L., and Tzeng, G. H. (2011). An integrated MCDM technique combined with DEMATEL for a novel cluster-weighted with ANP method. *Expert Systems with Applications*, *38*(3), 1417-1424.

Yang, Y. P. O., Shieh, H. M., Leu, J. D., and Tzeng, G. H. (2008). A novel hybrid MCDM model combined with DEMATEL and ANP with applications. *International Journal of Operations Research*, *5*(3), 160-168.

Yildirim, S., Temur, N., Kocaman, A., & Goktas, Y. (2004, May). What makes a good LMS: An analytical approach to assessment of LMSs. *In the Proceedings of the FIfth International Conference on Information Technology Based Higher Education and Training*, (pp. 125-130).

Yildirim, S., Temur, N., Kocaman, A., and Goktas, Y. (2004). What makes a good LMS: An analytical approach to assessment of LMSs. *In Proceedings of the 5th International Conference on Information Technology Based Higher Education and Training* (pp. 125-130). Istanbul, Turkey.

Zadeh, L. A. (1965). Fuzzy sets. *Information and Control*, *8*(3), 338-353.

APPENDIX A

SOURCE CODE OF THE DEVELOPED SYSTEM

```
using Evaluate_LMSs.Models;
using Evaluate_LMSs.ViewModel;
using System;
using System.Collections.Generic;
using System.Linq;
using System.Text;
using System.Web.Mvc;
using Accord.Math;
using System.Collections;

namespace Evaluate_LMSs.Controllers
{
   public class HomeController : Controller
   {
      public ActionResult Index()
      {
         return View();
      }
      public ActionResult selectCriteria()
      {
         List<CriteriaSelection> cS = new List<CriteriaSelection>();
         cS.Add(new CriteriaSelection() { CriteriaId = 1, CriteriaName = "Accessibility",
CriteriaSymbol = "Acc", CS= "Acc", CriteriaSign = "C1", IsChecked = false });
         cS.Add(new CriteriaSelection() { CriteriaId = 2, CriteriaName = "Administrative
Tools", CriteriaSymbol = "AT", CS = "AT", CriteriaSign = "C2", IsChecked = false });
         cS.Add(new CriteriaSelection() { CriteriaId = 3, CriteriaName =
"Communicability", CriteriaSymbol = "Com", CS = "Com", CriteriaSign = "C3",
IsChecked = false });
         cS.Add(new CriteriaSelection() { CriteriaId = 4, CriteriaName = "Compatibility",
CriteriaSymbol = "Cmp", CS = "Cmp", CriteriaSign = "C4", IsChecked = false });
```

```
        cS.Add(new CriteriaSelection() { CriteriaId = 5, CriteriaName = "Content
Management", CriteriaSymbol = "CM", CS = "CM", CriteriaSign = "C5", IsChecked =
false });
        cS.Add(new CriteriaSelection() { CriteriaId = 6, CriteriaName = "Efficiency",
CriteriaSymbol = "Eff", CS = "Eff", CriteriaSign = "C6", IsChecked = false });
        cS.Add(new CriteriaSelection() { CriteriaId = 7, CriteriaName = "Error Tolerance",
CriteriaSymbol = "ET", CS = "ET", CriteriaSign = "C7", IsChecked = false });
        cS.Add(new CriteriaSelection() { CriteriaId = 8, CriteriaName = "Evaluation
Tools", CriteriaSymbol = "EvT", CS = "EvT", CriteriaSign = "C8", IsChecked = false });
        cS.Add(new CriteriaSelection() { CriteriaId = 9, CriteriaName = "Flexibility",
CriteriaSymbol = "Fle", CS = "Fle", CriteriaSign = "C9", IsChecked = false });
        cS.Add(new CriteriaSelection() { CriteriaId = 10, CriteriaName = "Functionality",
CriteriaSymbol = "Fun", CS = "Fun", CriteriaSign = "C10", IsChecked = false });
        cS.Add(new CriteriaSelection() { CriteriaId = 11, CriteriaName = "Instruction
Tools", CriteriaSymbol = "IT", CS = "IT", CriteriaSign = "C11", IsChecked = false });
        cS.Add(new CriteriaSelection() { CriteriaId = 12, CriteriaName = "Learnability",
CriteriaSymbol = "Lea", CS = "Lea", CriteriaSign = "C12", IsChecked = false });
        cS.Add(new CriteriaSelection() { CriteriaId = 13, CriteriaName =
"Maintainability", CriteriaSymbol = "Man", CS = "Man", CriteriaSign = "C13", IsChecked
= false });
        cS.Add(new CriteriaSelection() { CriteriaId = 14, CriteriaName = "Multilanguage",
CriteriaSymbol = "Mul", CS = "Mul", CriteriaSign = "C14", IsChecked = false });
        cS.Add(new CriteriaSelection() { CriteriaId = 15, CriteriaName = "Navigability",
CriteriaSymbol = "Nav", CS = "Nav", CriteriaSign = "C15", IsChecked = false });
        cS.Add(new CriteriaSelection() { CriteriaId = 16, CriteriaName = "Pedagogical
Factors", CriteriaSymbol = "PF", CS = "PF", CriteriaSign = "C16", IsChecked = false });
        cS.Add(new CriteriaSelection() { CriteriaId = 17, CriteriaName =
"Personalisation", CriteriaSymbol = "Per", CS = "Per", CriteriaSign = "C17", IsChecked =
false });
        cS.Add(new CriteriaSelection() { CriteriaId = 18, CriteriaName = "Portability",
CriteriaSymbol = "Por", CS = "Por", CriteriaSign = "C18", IsChecked = false });
        cS.Add(new CriteriaSelection() { CriteriaId = 19, CriteriaName = "Reliability",
CriteriaSymbol = "Rel", CS = "Rel", CriteriaSign = "C19", IsChecked = false });
        cS.Add(new CriteriaSelection() { CriteriaId = 20, CriteriaName = "Security",
CriteriaSymbol = "Sec", CS = "Sec", CriteriaSign = "C20", IsChecked = false });
        cS.Add(new CriteriaSelection() { CriteriaId = 21, CriteriaName = "Support",
CriteriaSymbol = "Sup", CS = "Sup", CriteriaSign = "C21", IsChecked = false });
        cS.Add(new CriteriaSelection() { CriteriaId = 22, CriteriaName = "Sustainability",
CriteriaSymbol = "Sus", CS = "Sus", CriteriaSign = "C22", IsChecked = false });
        cS.Add(new CriteriaSelection() { CriteriaId = 23, CriteriaName = "Usability",
CriteriaSymbol = "Usa", CS = "Usa", CriteriaSign = "C23", IsChecked = false });
```

```
        cS.Add(new CriteriaSelection() { CriteriaId = 24, CriteriaName = "User
Satisfaction", CriteriaSymbol = "US", CS = "US", CriteriaSign = "C24", IsChecked = false
});
        CriteriaList choosen = new CriteriaList();
        choosen.chooseCriteria = cS;
        return View(choosen);
    }
    [HttpPost]
    public ActionResult selectCriteria(CriteriaList crList)
    {
        StringBuilder sb = new StringBuilder();
        foreach (var itm in crList.chooseCriteria)
        {
            if (itm.IsChecked)
            {
                GlobalArray.selectedCSymbolList.Add(itm.CriteriaSymbol);
Globals.selectedCriteria++; // incement selected criteria
                GlobalArray.selectedCriteriaList.Add(itm.CriteriaName);
GlobalArray.CSList.Add(itm.CS); //
                sb.Append(itm.CriteriaName + ",");
            }
        }
        string[] aA = GlobalArray.selectedCriteriaList.ToArray();
        List<string> sList = new List<string>();
        for (int i = 0; i <Globals.selectedCriteria; i++)
        {
            if (sList.Contains(GlobalArray.selectedCriteriaList[i]) == false)
            {
                sList.Add(GlobalArray.selectedCriteriaList[i]);
            }
        }
        if (Globals.selectedCriteria < 2) // Check if atleast 2 features are selected
        {
            return RedirectToAction("selectCriteria");
        }
        else
        {
            ViewBag.selectedFeature = "Selected LMSs are " + sb.ToString();
            return RedirectToAction("selectLMS");
        }
    }
```

```
}
```