



**Sudan University of Science and Technology**



**College of Graduate Studies**

**A Framework of Software Assessment in Medical Laboratory System  
(Case Study: Khartoum State)**

إطار عمل لتقييم البرمجيات في نظم المختبرات الطبية  
(دراسة حالة: ولاية الخرطوم)

**A Thesis Submitted in Partial Fulfillment of the Requirements of  
Master Degree in Information Technology**

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بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

الآية

قال تعالى:

( قَالَ الَّذِي عِنْدَهُ عِلْمٌ مِنَ الْكِتَابِ أَنَا آتِيكَ بِهِ قَبْلَ أَنْ يَرْتَدَّ إِلَيْكَ طَرْفُكَ فَلَمَّا رآه مُسْتَقِرًّا عِنْدَهُ قَالَ هَذَا مِنْ فَضْلِ رَبِّي لِيَبْلُوَنِي أَأَشْكُرُ أَمْ أَكْفُرُ وَمَنْ شَكَرَ فَإِنَّمَا يَنْشُرُ لِنَفْسِهِ وَمَنْ كَفَرَ فَإِنَّ رَبِّي غَنِيٌّ كَرِيمٌ )

صدق الله العظيم

سورة النمل الآية (40)

## الحمد لله

الحمد لله رب العالمين

الذي بنعمته تتم الصالحات ، الحمد لله عدد الحركات والسكون ، عدد ماغرد طير  
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صاحب العظمة والكبرياء ، يعلم ما في البطن والأحشاء ، فرق بين العروق والأمعاء ، أجرى فيهما الطعام  
والماء ، فسبحانك يا رب الأرض والسماء .

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يُحب من دعاه خفياً ، ويُجيب من ناداه نجياً ، ويزيدُ من كان منه حياً ، ويكرم من كان له وفياً ، ويهدي من  
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الذي سبحت له الشمس والنجوم الشهاب ، وناجاه الشجر والوحش والدواب ، والطير  
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First and last Praise is due to **Allah**,

To the soul of all my life, a symbol of love and healing balm, to white heart my beloved  
**Mother (Rahma)**

To the great man, the men marker, the generation educator and the school of life,  
**Soul of my father (Salih)**

To the source of my happiness my **brothers** and **sisters**

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To all of who encourage and support me

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## **Abstract**

The modern medical lab management system (MLMS) exists in an environment that produces a large amount of data with the advent of new technologies, both the quality and quantity of information are increasing exponentially. And he needs to use the best software and motivate the Health institutions to use the software to make it necessary to solve the problem of the buying decision for software of medical lab management system (MLMS). Health institutions are usually facing some problems with software vendors due to lack of knowledge on how to choose suitable software and owners often withhold important information, this leads to a misfit between the software and the owners. Proposed framework examines the different solutions to assess the software selection by Study MLMS available in the Sudanese market especially in Khartoum state, Select a long list of vendor and then flow up the assessment process, a select short list of the vendor, compare the short list of vendor finally select the best vendor & negotiate offer submitted. After using the framework and measuring the implications of its application in several aspects it was found that it helped to make it easier to choose between MLMS, make the assessment independent, Encourage use by small and medium-sized enterprises (SMEs) and creating a base for market place for research software. Develops this framework in the future to assess the hospital management system and ERP system in the Sudanese market and put it in the national information center as a tool to assess the software of MLMS. This study shows the importance of developing a systematic approach to the buying decision for software of MLMS and fill gaps between owners and vendors.

## المستخلص

نظم إدارة المختبرات الطبية الحديثة الموجودة في بيئة تنتج كمية كبيرة من البيانات مع ظهور تقنيات جديدة حيث تزداد جودة المعلومات وكميتها بشكل كبير والحاجة إلى استخدام أفضل البرمجيات لتحفيز المؤسسات الصحية على استخدام البرمجيات جعل من الضروري حل مشكلة قرار الشراء لبرمجيات نظم إدارة المختبرات الطبية. تواجه المؤسسات الصحية عادة بعض المشاكل مع بائعي البرمجيات بسبب نقص المعرفة حول كيفية اختيار البرمجيات المناسبة وغالبًا ما يتم حجب المعلومات الهامة عن المالكين، وهذا يؤدي إلى اختلال بين البرمجيات والمالكين. يدرس الإطار المقترح الحلول المختلفة الموجودة لتقييم اختيار البرمجيات من خلال دراسة نظم إدارة المختبرات الطبية المتوفرة في السوق السودانية وخاصةً في ولاية الخرطوم ، تحديد قائمة طويلة من البائعين ومن ثم اتباع اجراءت التقييم، إختيار قائمة قصيرة من البائعين، مقارنة القائمة القصيرة من البائعين واخيرا إختيار أفضل البائعين والتفاوض على العرض المقدم .بعد استخدام إطار العمل وقياس ما يترتب على تطبيقه فى عدة جوانب تم التوصل الى انه ساعد على تسهيل الاختيار بين نظم إدارة المختبرات الطبية ، وجعل عملية التقييم مستقلة ، شجع استخدامه من قبل الشركات الصغيرة والمتوسطة وخلق قواعدلأبحاث البرمجيات فى السوق. تطوير هذا الإطار فى المستقبل لتقييم نظام إدارة المستشفيات ونظام تخطيط موارد المؤسسات فى السوق السودانية ووضعها فى المركز القومى للمعلومات كأداة لتقييم برمجيات نظم المختبرات الطبية فى السودان .توضح هذه الدراسة أهمية تطوير منهجية منظمة لقرار الشراء لبرمجيات نظم المختبرات الطبية فى السودان وسد الفجوة بين المالكين والبائعين.

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## LIST of Abbreviation

AHP	Analytic Hierarchy Process
AMCs	Annual Maintenance Cost
CLR	Common Language Runtime
CMM	Capability Maturity Model
CRM	Customer Relation Management
CSFs	Critical Success Factors
ERP	Enterprise Resource Planning
FM	Facilities Management
HMS	Hospital Management System
GOMS	Goals Operators Methods Selections Rules
GSD	Global Software Development
IEEE	Institute of Electrical and Electronics Engineers
ISO	The International Organization for Standardization
LIMS	Laboratory Information Management System
MLMS	Medical Lab Management System
NIC	National Informatics Center
SEI	Software Engineering Institute
SLR	Systematic Literature Review
SMEs	Small and Medium-Sized Enterprises
SPI	Software Process Improvement
SPLAT	Software Product Line Process Assessment tool
SQA	Software Quality Assurance
TCO	Total Cost of Ownership

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**CHAPTER ONE**  
**INTRODUCTION**

## **Chapter One**

### **Introduction**

#### **1.1. Overview**

Application software helps organizations to perform effectively and efficiently in the competitive environment, thus providing customers with value-added services. The high significance of application software stimulates organizations to carry out a thorough evaluation of software project proposals that vendors submit with the aim of selecting the best proposal. This process entails a number of assessment criteria, multiple conflicting goals, and an increasingly turbulent business environment. Software projects are complex, dynamic, comprised of unstructured tasks, and dependent on diverse skill-sets of individuals. While analyzing complex adaptive systems and agile development practices, stated that software development is affected by internal, external, and social factors. As successful software project entails the following chronological stages: selecting the best software project proposal among several proposals that vendors submit, good implementation of the approved proposal, managing business processes, and examining the practicality of the system. However, a wrong software project selection would lead to software failure and weaken the system and thus adversely impact on company performance [1].

Medical lab Management System (MLMS) is software that is used in the laboratory for the management of samples, laboratory users, instruments, standards and other laboratory functions such as invoicing, plat management, and workflow automation. The modern MLMS exists in an environment that produces a large amount of data. With the advent of new technologies, both the quality and quantity of information is increasing exponentially. This increase in data can cause significant problems and methods are needed to manage it. One such method used is a MLMS [2].

To motivate the Health institutions it is necessary to identify the key factors and a key requirement for the MLMS solutions and also to find the different challenges to the implementation of different MLMS specific to the Health institutions. With the knowledge of these factors, it is easier to make a choice among the various MLMS available in the

market. With regard to implementing the MLMS in Health institutions, a major challenge is to integrate the traditional information system.

The methods used by the various solutions in the market to tackle this problem, must also be analyzed in process of making a decision not only from the point of Health institutions and research activities, but also from business aspect which uses ICT (Information and Communication Technology) to support other business functions (administrative, accounting, etc.) [3].

As an assessment of the health institution-domain based software solutions available in the market, we have chosen different MLM Systems in a way that they provide a sample over a wide range of attributes, including specific factors and features through build framework to assess software selection and effective MLMS.

## **1.2 Problem Statement**

health institutions are usually facing some problems with software vendors due to lack of knowledge on how to choose appropriate software and due to the fact that Health institution owners often withhold important information, this leads to a misfit between the software and the owners.

## **1.3 Proposed Solution**

Build framework help to choose the suitable software for the medical lab at the health institutions, generally in Sudan especially in Khartoum state.

## **1.4 Significance of the Study**

Software purchase is a grey zone, an underdeveloped area so it is important to develop a systematic approach to the buying decision for software of MLMS and helps health institutions to choose suitable software.

## **1.5 Objectives of the Study**

- To develop a systematic approach to the buying decision
- It helps to choose the suitable solution for MLMS.
- To fill gaps between owners and vendors.
- To make it easier to choose between MLMS and Incentivize the production of good MLMS.

## **1.6 Scope**

The suggested assessment framework could be applied for the medical Laboratory in Sudan especially in Khartoum state, the assessment process base on specified factors and features related to vendor and software of MLMS. MLMS under assessment consist of basic operations of medical Laboratory analysis, patient's info and staff, reports, dashboard. The assessment framework should help define what effective MLMS.

## **1.7 Methodology of the Study**

The health institution-domain based software solutions available in the market chosen different MLMS in a way that they provide a sample over a wide range of attributes, including specific factors and features related to vendor and software of MLMS base on the previous study in this field, through build framework by use visual studio2010, asp.net, SQL-server2014 and c# programming language to implement framework. The framework proposed examines the different MLMS solutions, to assess MLMS selection and effective MLMS.

## **1.8 Thesis Layout**

There are five chapters in this thesis. It is organized as follows: Chapter one gives an introduction about the research, defining the problem, significance, hypothechs, objectives, scope, methodology, and layout. Chapter two represents the Theoretical background and related works. Chapter three contains the methodology, techniques, and tools. Chapter four contains the test area, assessment framework description, and result. Chapter five is contained a conclusion and recommendations.



**CHAPTER TWO**  
**LITERATURE REVIEW**

## **Chapter Two**

### **Literature review**

#### **2.1 Introduction**

This chapter contains related works and background about the laboratory management system, Selecting Software, Best Practices in Choosing the Right Software Solution for Your Business, The Critical Success of Software.

#### **2.2 Laboratory Information Management System (LIMS)**

Laboratories around the world depend on a Laboratory information management system to manage data, assign rights, manage inventory, and more. A Laboratory Information Management System (LIMS) sometimes referred to as a Laboratory Information System (LIS) or Laboratory Management System (LMS), is a software-based laboratory and information management system with features that support a modern laboratory's operations. Key features include - but are not limited to - workflow and data tracking support, flexible architecture, and data exchange interfaces, which fully "support its use in regulated environments" the features and uses of a LIMS have evolved over the years from simple sample tracking to an enterprise resource planning tool that manages multiple aspects of laboratory informatics [4].

#### **2.3 How to choose the best apps for your business**

You want to use the best software for your work everyone does. Whether you're a cook or a web designer, well-made tools make your work more efficient, and more fun, but how do you choose the best software and how do you define "best", anyhow? There are more email, customer relationship management, and project management apps than you could ever test on your own. Ask your friends and colleagues, and each one will recommend a different tool. If you need a hammer, it's pretty easy to find a nice one. But software is more subjective: the best tool for you may not be the best for someone else [5].

#### **2.4 Tips to pick the best software:**

- **Focus on Your Business**

Apps are only tools to help you get stuff done. Try to make do with what you have for as long as you have, and only get new apps when you really need them.

- **Analyze your Needs**

Don't pick an app just to have something new figure out what you need from a tool, then research for an app that fits those needs.

- **Do Research**

Don't settle on the first app you find read reviews and ask for recommendations to make sure you've picked a great tool.

- **Ask for Help**

Companies want you to love their software, so ask for help when getting started.

- **Customize Apps for Your Needs**

Doesn't worry about defaults customize apps to fit the way you work Want to build your own app? Try doing it with a database builder app that lets you customize the way you view and save data.

- **Integrate Everything**

Automation can help connect the new app to everything else your team is using, to get more done faster.

- **Communicate**

Make sure everyone knows how to use the new app—and what they should be using it for.

- **Share Your Favorite Software**

Once you've found an app that works for you, tell others about it to help them simplify the software discovery process.

- **Company History & Experience**

The vendor needs to be sized up before we even go on to consider the software itself. Company background is essential because, unlike traditional companies, software companies are often small, & often beyond national boundaries. Since these companies would likely be handling our sensitive data, we need to do a background check.

- **Cost**

There's no denying the importance of cost-effectiveness in buying decisions across the board. Yet costs should be seen from a broad perspective, because low entry costs may well result in higher total costs along the product's life.

- **Ease of Use**

The software should have an intuitive interface, & the use of features should be pretty much self-evident. The shorter the learning curve training a new user, the better. The software should also have the ability to easily fit into the existing systems with which it will have to communicate. For example, collaboration software might allow you to use some features from your Outlook itself or even share Outlook data.

- **Familiarity**

The 'feel' of the software is another important criterion. The software should keep with the basic layout & navigation schemes we are used to. This makes for a quicker transition.

- **Security**

Security is a top consideration because the software company will likely be handling information critical to us – business, financial or personal. We need to be well assured of our data's security & there are no risks of it being compromised. This needs research, & the extensiveness of which depends on the sensitivity of our data [5].

## **2.5 The Cost Factor**

A cost-benefit analysis makes sense, and costs need to be compared with the software's range of functionalities.

Costs should be seen from a broad perspective, because low entry costs may well result in higher total costs along the product's life.

### **2.5.1 Features and price**

A cost-benefit analysis makes sense, & costs need to be compared with the software's range of features & functionalities. A document management system may not be the cheapest, but it may allow you to also set up a virtual office. Going for loads of features also constitutes a trap, because users never get around to using half of them [5].

### **2.5.2 Needs and Price**

Another question is whether there is an overlap between features & needs at all. Many features may not relate to needs sought to be addressed. You should clearly define your needs, & classify features as “needed features” & “features not needed”. Another possible scheme of classifying features could be “must have”, “nice to have”, & “future requirements” [5].

### **2.6 Security**

“Security is a top consideration because in many cases the software company will be handling information critical to us – business, financial or personal data.”

### **2.7 Software Buyers Must Be**

- Find the right software for your needs
- Free consultation to shortlist top systems
- Eliminate weeks of research
- Avoid costly software mistakes

### **2.8 Software Vendors Must Be**

- Access to high-quality leads
- All buyers are verified by phone
- Connect with buyers in niche markets
- Pay-per-lead demand generation

### **2.9 Critical Success Factors (Csfs) In Software Process Improvement**

The Software Engineering Institute statics shows that: the development and cost of software projects have become relatively very high due to the complexity of systems that make the software process more complex to be managed. Thus, it is essential to consider the SPI (Software process improvement) factors that directly affect the process and try to explore the best solution that helps in best management of the software process which ultimately produces the desired result i.e. help in meeting the basic attributes of the project i.e. time, delivery and the quality. While in the comprehensive literature review, it becomes obvious that CSFs play a vital role in the implementation of SPI and the change process. However, effectively used of factors such as management commitment; staff involvement,

etc. that influence the change process is still an argument question. A number of researches conducted in this regard but this question still unanswered. The literature review also explores that motivators and obstacles both have a positive and negative impact on the SPI process respectively. These motivators and obstacles also help in motivating and removing hurdles in the change process, if carefully identify and appropriately used. While in comprehensive literature reviews i.e. based on case studies, experience reports, research articles, and books. We identified ten critical success factors (see table 2.1) for details [6].

**Table 2.1: List of CSFs Identified Through Related Work**

<b>Categories</b>	<b>Priority</b>	<b>Percentage</b>
Senior Management Commitment	1	88%
Staff Involvement	2	71%
Experience Staff	3	53%
SPI awareness and Implementation SPI (Software Process Improvement)	4	53%
Training and mentoring	5	41%
Allocation of Resources	6	35%
Communication and Collaboration	7	35%
SPI goals and Objective	8	[25]%
Organization Culture	9	[25]%
Organization Politics	10	[25]%

## **2.10 Avoid Project Failure:**

Listed things should be kept in mind to avoid project failure as well as money and time loss:

- Functionalities and features of the software should match with the current business processes.
- Easy customization possibility, user-friendly and easy to use and understand.
- Software technology should not be very old and scalable whenever required.
- How good is the software in your vertical? And the cost of AMC (Annual Maintenance Cost) charges for software upgrades and updates, customization cost, hardware requirements/specifications if any, in short, an estimate of the TCO (Total Cost of Ownership) is obtained.

## **2.11 Related Works:**

- **Akinnuwesi, Uzoka, 2018 [1].**

This study focused on the development of the analytic hierarchy process (AHP) based model for software project proposal assessment, which will enable decision makers in the selection of a proposal that guarantees optimal performance when implemented. Developed an AHP-based model for the selection of software projects based on pair-wise comparison data from twenty domain experts AHP process. Sixty-four (64) variables were identified from the literature and hierarchically arranged into 4 levels based on the degree of preference. It was evident from the priority graph that functionality (35.26%), quality (22.00%) and usability (19.34%) had the higher priority weights, while cost (2.47%) and vendor services (6.26%) had the least. to the utility of AHP in software project proposal evaluation. AHP has been applied severally in decision modeling. An extensive literature search produced a high number of variables, which aggregated into semantic groups. Results indicate that functionality, quality, and usability are given high consideration in proposal evaluation, while cost and vendor services are not seen to be a critical factor.



- **pakrudin, Abdullah, ammonia, Jaafar, Mohammed, 2017 [15].**

This study explore the current literature that delves into the critical success factors (CSFs) for the implementation of Facilities Management (FM) in Healthcare industry in terms of the implementation, preparation of a compilation, and identification of any gaps that might exist, using the key term between facility management success and healthcare success, identified healthcare success factors. CSF constructs were then identified using the content analysis methodology and an inductive coding technique, a framework found for FM healthcare encompasses maintenance management, performance management, risk management, development, ICT and supply service management, cohesive and it can be well understood by all levels among the healthcare professionals, all the CSFs listed need to be more carefully researched to overcome the limitations of the literature reviewed.

- **(Nakai, Tsuda, Honda, Washizaki, Fukazawa, 2016 [4].**

This study explains how to measure their own software product quality, evaluate whether their software product has a high/low quality based on an international standard, identify sufficient/ insufficient quality (sub-) characteristics, determine weak qualities compared to other software products, and develop an objective interpretation. The results of a quality evaluation based on the framework help project stakeholders identify areas for improvement, as future work, introduce the framework to various domains and then, revise and refine measurements and evaluation plans to improve feasibility and usefulness. Additionally build the GQM model to combine clearly, the quality characteristics and metrics to clear interpretation of software quality. Define relationships between metrics and characteristics obviously, and verify the validity of these relationships through some case studies.

- **Khan, Keung, 2016 [10].**

This study identifying success factors and barriers to assist GSD (global software development) organizations for successful implementation of SPI (software process improvement) program. Accordingly, a systematic literature review approach adopted to identify the success factors and barriers. A total of nine success factors and six barriers were identified that could impact SPI.

using the criteria of the factors having a frequency >50% as critical, total four success factors were ranked as critical success factors, i.e. management commitment, staff involvement, allocated resources and pilot projects. Moreover, a total of four barriers was classified as critical barriers, i.e. lack of resources, inexperienced staff, organizational politics and time pressure. Used SLR (systematic literature review) approach for the identification of critical success factors (CSFs) that can affect the contract management activities in distributed development the findings of this study can possibly result into tackling the implementation of SPI program, which can lead towards the progression and success of the organization.

- **Garefalakis, Mantalis, Vourgourakis, Spinthiropoulos, Lemonakis, 2016 [8].**

This study discusses, among other things, the importance of the right decision, by the management of a healthcare unit, regarding the choice of the appropriate ERP system, followed by its installation and implementation. The critical points in the adoption of ERP systems by a health organization are the selection of the appropriate ERP system, the right preparation, the maintenance of the project schedule and the proper staff training. The result of any deviations or dysfunctions ranges from a slight increase at cost until the total failure of the implementation, on the other hand, the right adoption increases productivity significantly. Since most operating costs of health care are considerably reduced, these funds can be reallocated to other significant needs.

- **Ahmed, Capretz, 2015 [5].**

This study using certain rules for developing and managing a software product line are put forward additionally, a fuzzy logic based software product line process assessment tool (SPLAT) has been designed and implemented on the basis of developed rules for software product line process assessment, this study will help to evaluate their current process maturity level, and this, in turn, will assist management's decision-making process in their efforts to improve the productivity of the development process. SPLAT can be used to assess the process maturity level of software product line, and it provides an opportunity to handle imprecision and uncertainty present in software process variables, The results of the developed software product line process assessment approach were compared with the

existing CMM-level (the Capability Maturity Model) of the organization in order to evaluate the reliability of the presented approach and to find out how effectively an organization can execute Software product line process when it has already achieved a certain CMM level.

- **Miguel, Mauricio, Rodríguez, 2014 [20].**

This study describes the main models with their strengths and point out some deficiencies, conclude that in the present age, focus on the quality of the software product, that is, in the final product rather than on the processes that lead to its construction, even though they are closely related. The use of models is an acceptable means to support quality management software products. According to ISO/IEC IS 9126-1 [2] a quality model is "the set of characteristics and the relationships between them that provides the basis for specifying quality requirements and evaluation" The models to evaluate the quality of software have been constructed defining the fundamental factors (also called characteristics) and within each of them the sub factors (or sub-characteristics). Metrics are assigned to each sub factor for the real evaluation. There are very general models for assessing software quality and hence they are difficult to apply to specific cases. Also there exist tailored quality models whose range is in the small domain, using as starting model the ISO 9126. Models for Free/Open source emphasize the participation of community members.

- **Purna Sudhakar, 2012 [16].**

This study explains the Purpose existing models of critical success factors of software projects have less concentration on communication, team, project management, and product-related factors. Hence, develop a conceptual model of critical success factors (CSFs) for software development projects, categorize the success factors, finding the factors in each category and highlighting the product, team, project management and communication factors as important categories of success factors for software projects. A conceptual model and seven categories of success factors comprising a total of 80 success factors for software development projects were identified based on the thorough literature review a total of 35 CSFs from seven CSF categories are identified from secondary research of the CSFs for software development projects. The project managers working in

the industry can benefit from the mentioned critical success factors and the categories of factors by concentration on them while planning and executing software projects. The conceptual model, categorization of CSFs, identifying 35 CSFs for software projects and highlighting product, team and communication factors are major contributions of this research work.

- **Niazi, Wilson, Zowghi, 2006 [18].**

Present finding from the empirical study conducted of the CSFs, this includes 34 Software process improvement (SPI) practitioners from [25] companies and, 5 companies are among those which have been awarded best process achievement by IEEE Computer Society. In addition to the empirical study, 47 published experienced reports, case studies and articles were analyzed. Exploring the issues related to SPI implementation and provided detail knowledge to SPI practitioners about the positive impacts of these issues and in the implementation process. Seven factors were identified namely: (higher management support, training, awareness, allocation of resources, staff involvement, experienced staff and defined SPI implementation methodology) that are generally considered critical for successfully implementing SPI. While a comparison of the empirical results with the analyzed literature they identified two new CSFs i.e. (SPI awareness and defined SPI implementation methodology) that are not available in the literature.

## **2.12 Summary:**

The similarity between the related works and the current study is that the importance of the right decision, by the owners of health institutions, regarding the choice of the appropriate medical laboratory system. The differentials between this work and other different techniques and tools used in each study to solve the problem of how to select the appropriate software. Medical information increases dramatically daily and also developed the technology used quickly.

**CHAPTER THREE**  
**METHODOLOGY**

## **Chapter Three**

### **Methodology**

#### **3.1 Introduction**

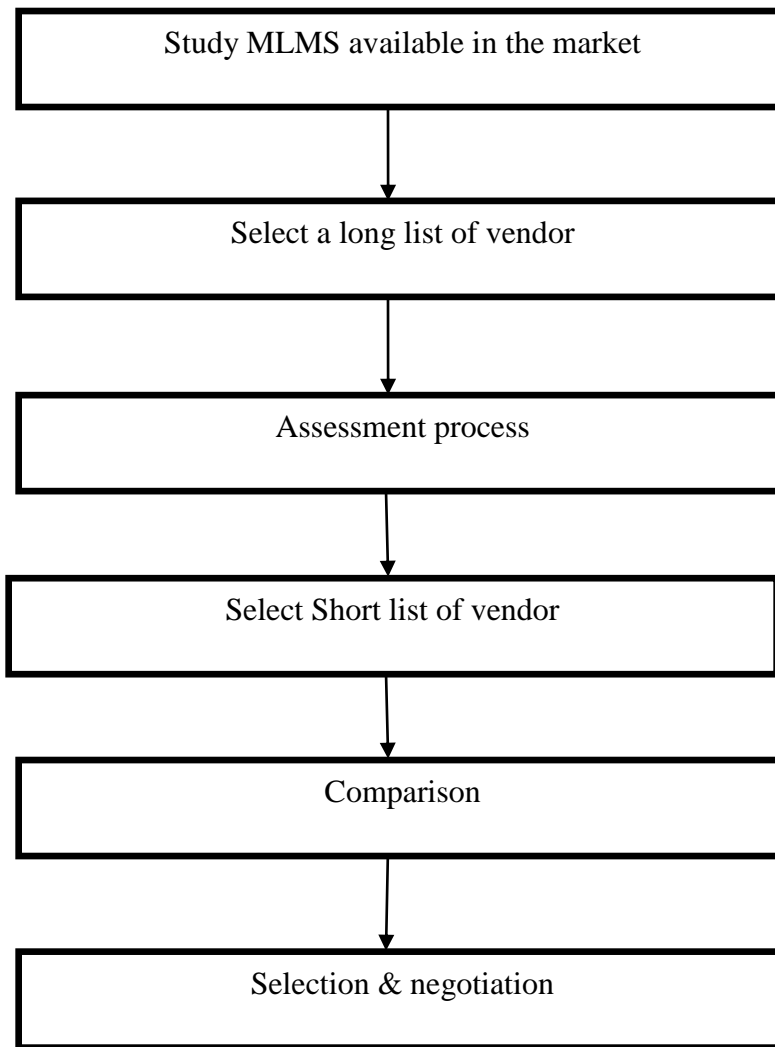
This chapter contains the methodology of research, tools, and techniques which is used to design and implement assessment framework, Assessment process, how to calculate weight or points for assessment and study of an available solution in the Sudanese market, especially in Khartoum state.

#### **3.2 Methodology**

As an assess of the health institution-domain based software solutions available in the market we have chosen different MLM Systems in a way that they provide a sample over a wide range of attributes, including specified factors and features related to vendor and software of MLMS, through design and implement framework by using visual studio2010, asp.net, and SQL-server2014 and c# programming language.

The proposed framework assess MLMS software selection and help to select suitable MLMS from available solutions in Sudan, it defines a framework by which any future in any new health institution systems MLMS in particular.

3.2.1 **Figure 3.1 a Framework of Assessment for MLMS**



### **3.3 Visual Studio 2010**

Visual Studio 2010 has something for every developer the new editor, now using Windows Presentation Foundation, delivers a more flexible, feature-rich environment that supports concepts such as the use of multiple monitors.

This enables a developer to have one monitor with code, another with the user interface designer, and yet another with database structure [7].

### **3.4 ASP.NET**

ASP.NET is an open-source server-side web application framework designed for web development to produce dynamic web pages. It was developed by Microsoft to allow programmers to build dynamic web sites, web applications and web services, it was first released in January 2002 with version 1.0 of the .NET Framework, and is the successor to Microsoft's Active Server Pages (ASP) technology. ASP.NET is built on the Common Language Runtime (CLR), allowing programmers to write ASP.NET code using any supported .NET language. The ASP.NET SOAP extension framework allows ASP.NET components to process SOAP messages [7].

### **3.5 SQL SERVER 2014**

SQL Server 2014 is a relational database management system (RDBMS) designed for the enterprise environment, released on April 1, 2014, SQL Server 2014 runs on the Structured Query Language (SQL), but has several notable differences from its immediate predecessor SQL Server 2012 [7].



### **3.6 The Criteria of Assessment Framework for Medical Lab Management System**

**I:** study available solutions of MLMS in the Sudanese market through (tenders, search in the website of the vendor, market study).

**II:** a select long list.

**III:** follow the assessment process base on specified factors and features.

**IV:** technical Assessment by the professional user or IT team parallel with customer assessment (through selected value and from point of view customer).

**V:** select short list vendor.

**VI:** compare a short list of the vendor to select the best.

**VII:** negotiate quotation whit vendor.

### **3.7 Assessment Process**

- **Vendor Profile**

Assess for (number of previous projects, years of experience, number of the customers, and time to deliver the project).

- **Software Information's**

Assess for (deployment, number of the users, a technology used, software certificate, and free trial).

- **Software Features**

Assess for (Data Tracking Support, Flexible Function, Data Exchange Interface, Data Analysis Auditing, Data Security, Lab Instrument Interface, Multi-location Printing, Online Instrumentation, Physician Test Panels, Procedure Based Billing, Sample Tracking).

- **Standards Used**

Assess for (the international standard used such as ISO, IEE, and SEI or non-standard used).

- **Cost**

Assess for (organization budget, quotation).

- **Offers**

Assess for (free technical support, free training, free backup, free hosting, and free upgrading).

- **Key requirements**

Assess for eight key requirements (The reception and login of sample its associated customer data, the assignment scheduling tracking of the sample and the associated analytical workload, The processing and quality control associated with the sample and the utilized equipment and inventory, The storage of data associated with sample analysis, The inspection approval, and compilation of the sample data for reporting and, or further analysis, Easy-to-use, user friendly and feature-rich, Efficiently works on all devices (desktop, mobile, tablet), Integrated with EHR system of the healthcare practice).

- **Training and technical support**

Assess for (the type of training, the period of training, type of technical support).

- **Technical assessment**

Assess for (Functionality, System flexibility, Usability, Quality, Vendor service).

- **Functionality**

Assess for (if MLMS is full content if MLMS is interoperability and completeness if MLMS is ease of customization).

- **System flexibility**

Assess for (if MLMS is adaptable if MLMS is integral).

- **Usability**

Assess for (if user interest when use MLMS, if MLMS Ease of use, if MLMS support user experience).

- **Quality**

Assess for (if MLMS is reliable, if MLMS is efficiency).

- **Vendor service**

Assess for (if vendor have a good experience if vendor have a good technical capability).

- **Involve customer assessment**

Assess for (easy to use MLMS, easy to learn MLMS, user-friendliness when using MLMS, customer support when using MLMS, a familiarity of MLMS, proper feedback of MLMS, good features of MLMS).

### 3.8 The Weight for Assessment

Category	Weight	Vendor		
		Vendor1	Vendor2	Vvendor3
Vendor profile	12			
Software information's	20			
Software features	11			
Cost	10			
Offers	5			
Training and technical support	10			
Key requirement	8			
Standards used	4			
Customer assessment	8			
Technical assessment	12			
<b>Total</b>	<b>100</b>			
	<b>Selection</b>			

The weight or points for the assessment process were calculated in this framework based on previous studies.

### 3.9 Study of Available Solution in the Sudan

As a selection of the health institution-domain based MLMS solutions available in Sudan, we have chosen different MLMS in a way that they provide a sample over a wide range of attributes, including specific factors and features related to vendor and software of MLMS, technology or platform on which the solutions are built and so on.

**Table 3.2: Products and Vendors Details in the Sudanese Market**

<b>Product details</b>	<b>Torex medical lab</b>	<b>Rainbow lab</b>	<b>Smart lab</b>	<b>M Lab</b>
<b>Starting Price</b>	20,000 SDG	25,000 SDG  <ul style="list-style-type: none"> <li><b>Pricing Details</b>  Price includes first-year full support. Additional support</li> </ul>	15,000 SDG	50,000 SDG/year  <ul style="list-style-type: none"> <li><b>Pricing Details</b>  10.000 Per laboratory workstation per year. Free for qualifying organizations</li> </ul>
<b>Free Trial</b>	No	No	Yes	No
<b>Deployment</b>	Installed-Windows Installed-Linux	Installed – Windows	Installed – Windows	Installed - Windows
<b>Training</b>	Session	Session user guideline	Documentation Live Online	Session

<b>Support</b>	Online business hours24/7  On-call	Online business hours 24/7  On-call	Online business Hours 24/7  On-call	Online business hours24/7  On-call
<b>Vendor Details</b>	Torex software  <a href="http://www.torexsoftware.com">www.torexsoftware.com</a>  <ul style="list-style-type: none"> <li>• Founded 2014</li> <li>• Sudan - Khartoum</li> </ul>	Rainbow ICT  <a href="http://www.rainbow-it.com">www.rainbow-it.com</a>  <ul style="list-style-type: none"> <li>• Founded 2010</li> <li>• Sudan- Khartoum</li> </ul>	Smart solution  <a href="http://www.smartsolutionsoft.com">www.smartsolutionsoft.com</a>  <ul style="list-style-type: none"> <li>• Founded 2000</li> <li>• Sudan- Khartoum</li> </ul>	M-Technology  <a href="http://www.mtechnology.com">www.mtechnology.com</a>  <ul style="list-style-type: none"> <li>• Founded 2008</li> <li>• Sudan-Khartoum</li> </ul>
<b>Features</b>	(1) Ease of use (2) Technically Rich (3) Smart Solutions (4) Simplistic UI	(1)Data Security (2)Sample Tracking (3)Inventory Management (4)Reporting and Statistics	(1) All-around support for all medical lab requirements (2) patient-oriented approach (3) Dynamic Report-making (4) Support for patient monitoring	(1) Optimized for customization (2) Hosted on Cloud Servers (3) Flexible pricing

### **3.10 Summary**

Four vendors were examined in the Sudanese market in Khartoum State by studying and comparing through products and vendor details (starting price, free trial, deployment, training, and support, vendor details, and features of software).

These selected vendors will be tested by the proposed assessment framework for getting a result.

**CHAPTER FOUR**  
**RESULTS AND DISCUSSION**

## Chapter Four

### Results and Discussion

#### 4.1 Introduction

This chapter contains the definition of a medical lab, test area also some historical background information is given, assessment framework description and results after use framework.

#### 4.2 LABORATORIES

Medical lab Management System (MLMS) is software is used in the laboratory for the management of samples, laboratory users, instruments, standards and other laboratory functions such as invoicing, plat management, and workflow automation, the modern MLMS exists in an environment that produces a large amount of data. With the advent of new technologies, both the quality and quantity of information is increasing exponentially. This increase in data can cause significant problems and methods are needed to manage it. One such method used is a MLMS [2].

#### 4.3 Khartoum State

Khartoum, the capital of Sudan is divided into three towns (Omdurman – Khartoum – Bahri), there are a number of Laboratories and health institutions, while distributed in the state center and various neighborhoods, the most famous of which is the National central Laboratory.

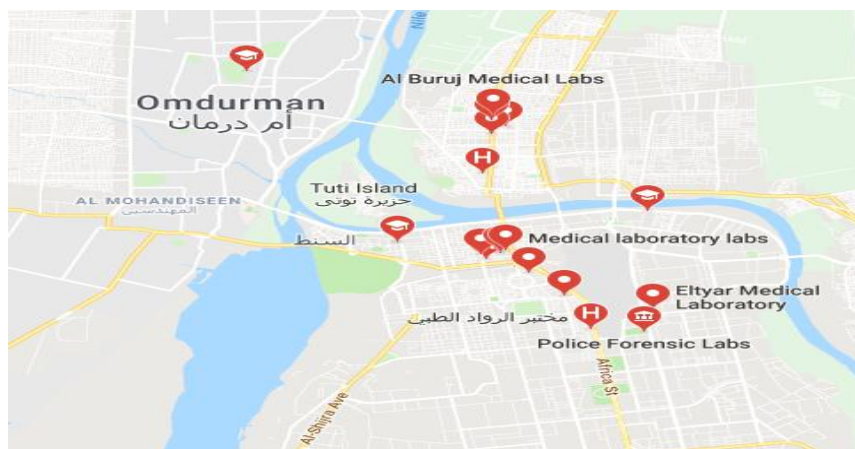


Figure 4.1: Map of Laboratories in Khartoum State



#### **4.4 The Test Area**

The presence of 3,000 labs in the capital, of which 70% are private, the required tests from international health are 25 thousand examinations, knowing that the best laboratories in Sudan have a list of tests available, which does not exceed 180 examinations [28], because availability of data about the laborites in Khartoum therefore, it was decided to select Khartoum state.

#### **4.5 Assessment Framework Description**

This framework helps to choose the suitable software for laboratories, study MLMS available in the Sudanese market and then makes the long list of vendor, assessment process, establish a short list of the vendor, comparing the short list of a vendor, select and negotiate offers with a vendor.

- Assess the vendor profile through a number of previous projects, years of experience, number of customers, time to deliver the project.
- Assess info about software through the operating system used, the number of users, a technology used software certificates, and free trial for software.
- Assess software features
- Assess standards used for software production and development
- Assess the cost through compare Organization budget with quotation
- Assess offers provided by the vendor
- Assess some key requirement of MLMS
- Assess training and support provided by the vendor
- With parallel of technical assessment involve customer assessment

Finally, compare shortlist of vendors to select the best depend on a report of the framework and Knowing that there is a detailed explanation of the Assessment framework interfaces in the appendices.

#### **4.5.1 The User of the Assessment Framework**

Authorized users only login.

#### **4.5.2 User Functions**

- Input all info about MLMS and vendor
- Follow the process of assessment
- Demanding report

#### **4.5.3 Assessment Framework Functions**

- Retrieving results according to the input data by the user
- Comparing the short list of vendor
- Showing the best vendor

#### **4.6 Assessment Framework Components**

The application consists of two components: hardware and software.

##### **4.6.1 Hardware Components**

- Server or computer works as a server
- Any commuter with the windows operating system

##### **4.6.2 Software Components**

- **User part:** windows, browser.
- **Server part:** Consists of the SQL-server database which contains the data and uses C# language accessing the database.

## 4.7 Report Interface

# Report

Name	Address	Website	Phone	
Torex Software	Khartoum	www.torex.com	922362095	<a href="#">Add To Comparason</a>
Rainbow ICT	Khartoum	www.rainbow ict.com	0123457540	<a href="#">Add To Comparason</a>
Smart solution	Khartoum	www.smart solution soft.com	0909308014	<a href="#">Add To Comparason</a>
M-Technology	bahri	www.mtechnology.com	0912962574	<a href="#">Add To Comparason</a>
Mayo medical alb	Khartoum	www.mayo medical lab.com	0912962574	<a href="#">Add To Comparason</a>

Add To Comparason

	VendorProfileId	Name
<a href="#">Delete</a>	13	Torex Software
<a href="#">Delete</a>	14	Rainbow ICT
<a href="#">Delete</a>	15	Smart solution
<a href="#">Delete</a>	16	M-Technology
<a href="#">Delete</a>	17	Mayo medical alb

Comparason Software

Figure (13): Report interface-1

This Figure illustrates the report of the assessment framework to assess the vendor through all info about the vendor which is entered already.

### Assessment Report

Category	Weight	Vendor		
		Torex Software	Rainbow ICT	Smart solution
Vendor Profile	12	4	8	12
Software Information	20	12	12	14
Software Features	11	7	8	8
Cost	10	5	5	5
Offers	5	2	3	2
Training And Technical Support	10	7	7	3
Key Requirement	8	3	2	3
Standards Used	4	3	4	2
Customer Assessment	8	4	6	7
Technical Assessment	12	6	7	10
<b>Total</b>	<b>100</b>	<b><u>53</u></b>	<b><u>62</u></b>	<b><u>66</u></b>
	Selection			

The First  The Third   
The Second  The equal

Figure (14): report interface-2

This Figure illustrates the assessment report of the vendor to compare the vendor through a short list of vendor showing the name of the vendor and the points related to the vendor, the first vendor show in green color, the second vendor show in yellow color, the third vendor show in red color.

Assessment Report				
Category	Weight	Vendor		
Vendor Profile	12	12	4	4
Software Information	20	11	0	0
Software Features	11	0	0	0
Cost	10	0	0	0
Offers	5	0	0	0
Training And Technical Support	10	0	0	0
Key Requirement	8	0	0	0
Standards Used	4	0	0	0
Customer Assessment	8	0	0	0
Technical Assessment	12	0	0	0
<b>Total</b>	<b>100</b>	<b>23</b>	<b>4</b>	<b>4</b>
	<b>Selection</b>			




The First	
The Second	
The Third	

Figure (4.15): report interface-3

This Figure illustrates the assessment report of the vendor in case if the two or three vendors are the same show in gray color

## 4.8 Results

After using the framework, the results are shown as follows:

**Table 4 .4: The Result after Use Framework**

<b>Researcher</b>	<b>Software developer</b>	<b>Industry</b>	<b>Funder</b>
Make it easier to choose between MLMS	Increase recognition of good practice	Encourage use by small and medium-sized enterprises (SMEs)	Enable more efficient investment
Incentivize production of good MLMS	Facilitate discovery and reuse		Creating a base for market place for research software
Independent assessment			

**CHAPTER FIVE**  
**CONCLUSION AND RECOMMENDATIONS**

## **Chapter Five**

### **Conclusion and Recommendations**

#### **5.1 Introduction**

This chapter contains the conclusion of research and recommendation which is recommended by the researcher to evaluate the framework in the future.

#### **5.2 Conclusions**

This study shows the importance of developing a systematic approach to the buying decision for software of MLMS and fill gaps between owners and vendors. The need to use the best software for business and motivate the Health institutions to use the software make it necessary to identify some factors and features related to vendor and software solutions these big challenges lead to the design and implement the assessment framework. Develop and implement a framework help to choose suitable software for the medical lab, after testing the framework and showing the results it's easy to choose between MLMS, Reduce cost of assessment through the self-assessment, Independent and objective assessment. In the near future, this framework will help everyone to assess the hospital management system and ERP system in the Sudanese market. This study achieves to a systematic approach to the buying decision for software of MLMS and fills gaps between owners and vendors.

### **5.3 Recommendations**

After the completion of this research and the many tests carried out, we recommend the following to improve the system:

- Adding strong criteria to the assessment process.
- Adding the SQA document and risk plan to the assessment process.
- Adding data mining and SPSS techniques to obtain accurate measurements for the assessment process.
- Making the calculation of the weight for the assessment process more accurate.
- Making the framework working properly to assess all software in the Sudanese market.



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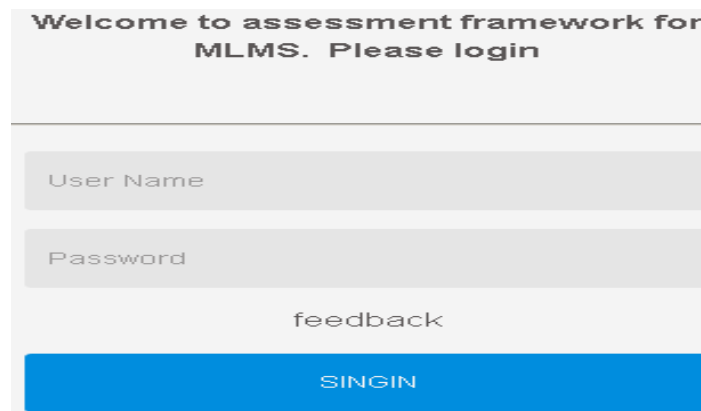
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## **APPENDICES**

## Appendix (1)

### Implementation and Assessment Framework Interfaces:

#### Login Interface:



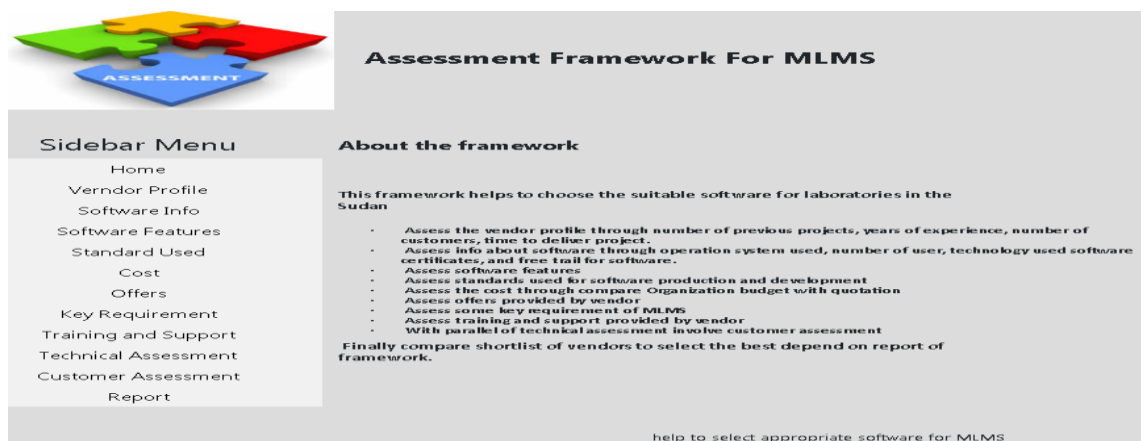
The login interface features a light gray background. At the top, a white box contains the text "Welcome to assessment framework for MLMS. Please login". Below this are two input fields: "User Name" and "Password". A "feedback" link is positioned below the password field. At the bottom, a prominent blue button is labeled "SINGIN".

Figure (1): login interface

This Figure illustrates the login screen in the application, only authorized user after entering username and password can be singing to assessment framework.

## Appendix (2)

#### The Main Interface:



The main interface is titled "Assessment Framework For MLMS". It features a sidebar menu on the left and a main content area on the right. The sidebar menu includes: Home, Verndor Profile, Software Info, Software Features, Standard Used, Cost, Offers, Key Requirement, Training and Support, Technical Assessment, Customer Assessment, and Report. The main content area contains the following text:

**About the framework**

This framework helps to choose the suitable software for laboratories in the Sudan

- Assess the vendor profile through number of previous projects, years of experience, number of customers, time to deliver project.
- Assess info about software through operation system used, number of user, technology used software certificates, and free trial for software.
- Assess software features
- Assess standards used for software production and development
- Assess the cost through compare Organization budget with quotation
- Assess offers provided by vendor
- Assess some key requirement of MLMS
- Assess training and support provided by vendor
- With parallel of technical assessment involve customer assessment

Finally compare shortlist of vendors to select the best depend on report of framework.

help to select appropriate software for MLMS

Figure (2): the main interface

This Figure illustrates the main screen, to start the assessment process user selects a specified button from sidebar menu (vendor profile, software info, software features, the standard used, cost, offers, key requirements, training and support, technical assessment, customer assessment).

### Appendix (3)

#### Vendor Profile Interface:



The screenshot shows a form titled "Vendor Profile". It contains the following fields and options:

Name	<input type="text"/>
Address	<input type="text"/>
Website	<input type="text"/>
Phone	<input type="text"/>
No Previous Projects	0 - 100
Years of Experience	0 - 3 years
No Of Customers	0 - 50 customers
Time To Deliver the Project	1 W - 4 W

Save

Figure (3): vendor profile interface

This Figure illustrates the vendor profile screen to assess the vendor user to enter the info about the vendor and chose the selected value to calculate the points of assessment vendor profile.

### Appendix (4)

#### Software Info Interface:



The screenshot shows a form titled "Software Info". It contains the following fields and options:

Vendor Name	Rainbow ICT
Version	<input type="text"/>
Programming Language	<input type="text"/>
Release Date	<input type="text"/>
Deployment	Windows
Number of User	Unlimited
Technology Used	Open source
Software Certificate	Yes
Free Trial	Yes

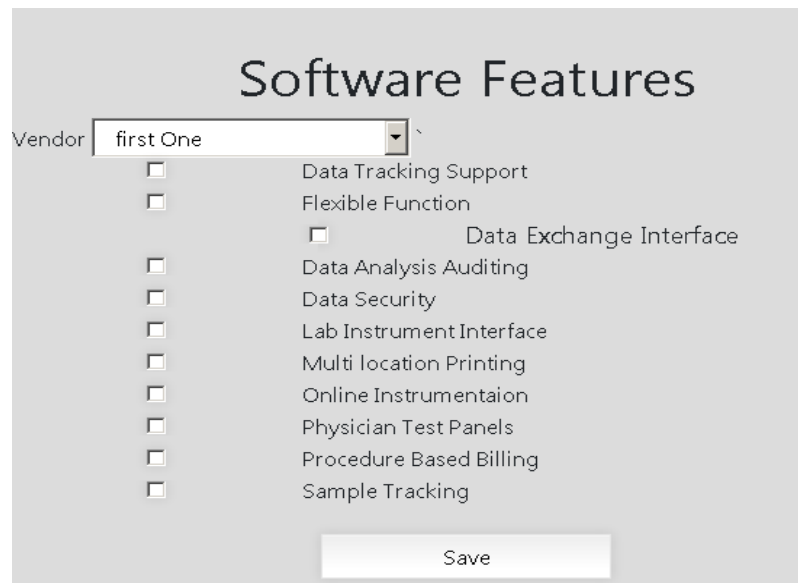
Save

Figure (4): software info interface

This Figure illustrates the software information screen to assess the MLMS user firstly must be select the vendor name, enter the info about software information, chose the selected value to calculate the points of software info.

## Appendix (5)

### Software Features Interface:



The screenshot displays a web interface titled "Software Features". At the top, there is a dropdown menu labeled "Vendor" with the text "first One" and a downward arrow. Below this, there is a list of features, each with a checkbox to its left. The features listed are: Data Tracking Support, Flexible Function, Data Exchange Interface, Data Analysis Auditing, Data Security, Lab Instrument Interface, Multi location Printing, Online Instrumentaion, Physician Test Panels, Procedure Based Billing, and Sample Tracking. At the bottom center of the interface is a "Save" button.

Figure (5): software features interface

This Figure illustrates the software features screen to assess the MLMS features user firstly must be select the vendor name, tick on the checkbox value to calculate the points of software features.

## Appendix (6)

### Standards Used Interface:



Standard Used

Vendor: Torex Software

Standard: none

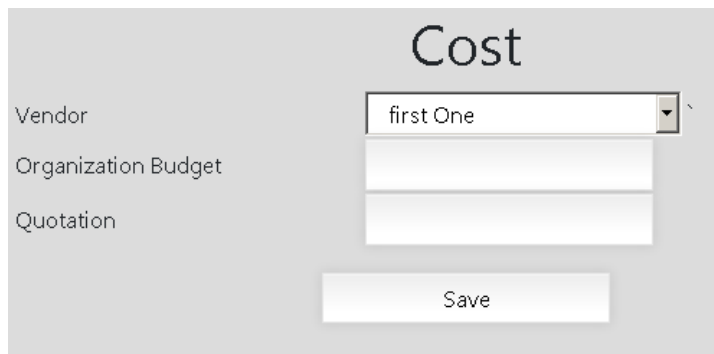
Save

Figure (6): standard user interface

This Figure illustrates the standard used screen to assess the standards used to produce MLMS represented by vendor specified already through the selected value and calculate the points of the standard used, the user must be select the vendor name.

## Appendix (7)

### Cost Interface:



Cost

Vendor: first One

Organization Budget: [Empty]

Quotation: [Empty]

Save

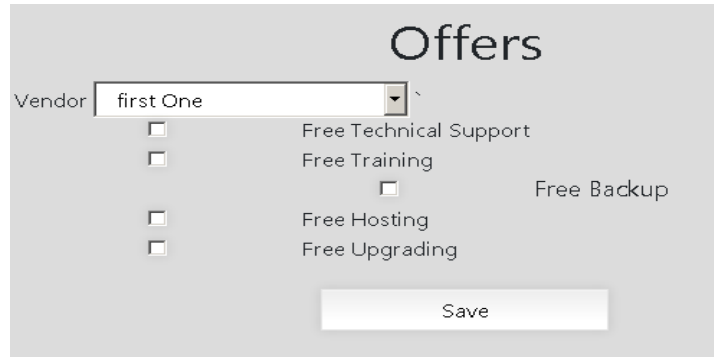
Figure (7): cost interface

This Figure illustrates the cost screen, then user first must be selecting the vendor name to assess the cost of MLMS through compare organization budget and quotation the first scenario: organization budget equal the quotation, second scenario: organization budget greater than a quotation, third scenario: organization budget less than a quotation.



## Appendix (8)

### Offers Interface:



The screenshot shows a web interface titled "Offers". At the top left, there is a "Vendor" label followed by a dropdown menu containing the text "first One". Below this, there are five checkboxes, each followed by a text label: "Free Technical Support", "Free Training", "Free Backup", "Free Hosting", and "Free Upgrading". At the bottom center, there is a "Save" button.

Figure (8): offers interface

This Figure illustrates the offers screen user firstly must be select the vendor name, assess to offers through the checkbox value related to the presented offers.

## Appendix (9)

### Key Requirement Interface:



The screenshot shows a web interface titled "Key Requirement". At the top right, there is a "Vendor" label followed by a dropdown menu containing the text "first One". Below this, there is a list of seven checkboxes, each followed by a text label: "The reception and login of sample it is associateed customer data", "The processing and quality control associated with the sample and the utilized equipment and inventory", "The assignment scheduling and tracking of the sample and the associated analytical workload", "The storage of data associated with the sample analysis", "The inspection approval and compilation of the sample data for reporting and further analysis", "Easy to use, user friendly and feature rich", "Efficiently works on all devices (desktop,mobile and tablet)", and "Integrated with ERH system of the healthcare practice". At the bottom center, there is a "Save" button.

Figure (9): key requirement interface

This Figure illustrates the key requirement screen to assess the key requirement specified already through the selected checkbox value and calculate the points of key requirement, a user must be select the vendor name.

### Appendix (10)

#### Training and Technical Support Interface:



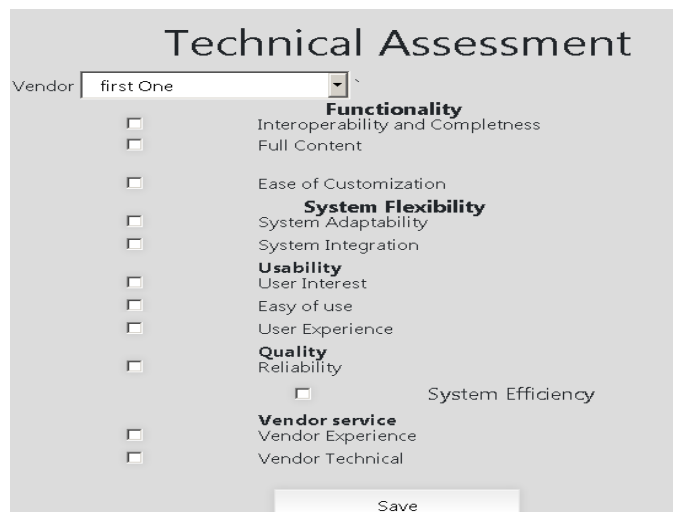
The screenshot shows a form titled "Training and Support". It contains four dropdown menus: "Vendor" (selected: first One), "Type of Training" (selected: Session), "Period of Training" (selected: 1W), and "Type of Technical Support" (selected: ON call). A "Save" button is located at the bottom center of the form.

Figure (10): training and technical support interface

This Figure illustrates the training and technical support screen to assess facilities of training and technical support through the selected value and calculate the points of training and support, a user must be select the vendor name.

### Appendix (11)

#### Technical assessment interface



The screenshot shows a form titled "Technical Assessment". It features a "Vendor" dropdown menu (selected: first One) and a list of assessment criteria, each with a checkbox:

- Functionality**
  - Interoperability and Completeness
  - Full Content
- Ease of Customization
- System Flexibility**
  - System Adaptability
  - System Integration
- Usability**
  - User Interest
  - Easy of use
  - User Experience
- Quality**
  - Reliability
  - System Efficiency
- Vendor service**
  - Vendor Experience
  - Vendor Technical

A "Save" button is located at the bottom center of the form.

Figure (11): a technical assessment

This Figure illustrates the technical assessment to assess the MLMS from point of view technical user parallel with customer assessment through the checkbox value and calculate the points of technical assessment.

## Appendix (12)

### Customer Assessment Interface:



The screenshot displays a web form titled "Customer Assessment". On the left, there is a label "Vendor" above a vertical list of checkboxes. To the right of these checkboxes are the following assessment criteria: "Easy to Use", "Easy to learn", "User Friendliness", "Customer Support", "Familiarity", "Proper Feedback", "Good Features", and "Comfortable Using Software". At the top right, there is a dropdown menu with "first One" selected. At the bottom center, there is a "Save" button.

Figure (12): customer assessment interface

This Figure illustrates the customer assessment to assess the MLMS from point of view customers parallel with technical assessment through the checkbox value and calculate the points of customer assessment, a user must be select the vendor name.