ESTGOH

Escola Superior de Tecnologia e Gestão de Oliveira do Hospital

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Laboratory Information Management System

Study & Development of LIMS Web Platform Application for CTCV - Coimbra

Relatório apresentado com vista à obtenção do grau de Mestre no âmbito da realização do ciclo de estudos de Mestrado em Informática Aplicada

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Resumo

A *World Wide Web* alterou e melhorou diversos aspetos do nosso dia a dia. Também alterou muito o modo como o *software* de computador é construído. Esta evolução profunda do desenvolvimento de *software* fez com que muitos na indústria de *software* mudassem sua maneira de desenvolver *software*. Neste projeto, o Sistema de Gestão de Informações de Laboratório (LIMS) para funcionários de pequenas empresas foi projetado e desenvolvido usando a metodologia *Throwaway Prototyping* com arquitetura *web*.

Diferentes tipos de plataformas de desenvolvimento estão disponíveis no mercado para desenvolvimento de aplicações, mas conforme o requisito da empresa, esta aplicação foi desenvolvida na plataforma .net da Microsoft. Esta aplicação *web* permite o acesso à informação em diferentes dispositivos, como *tablet* ou *smartphone* de qualquer parte do mundo. A principal característica desta aplicação passa por oferecer a possibilidade de monitorizar a atividade realizada pelos intervenientes (quem fez o quê? Quando? Quais os resultados?).

O sistema usa um sistema de gerenciamento de bases de dados relacional padrão (RDBMS) e uma interface *browser-independent* para entrada e recuperação de dados. (A tecnologia de 3 camadas) O sistema resultante orienta os utilizadores nas etapas do fluxo de trabalho do laboratório, facilitando a gestão e rastreamento de todos os testes e resultados de testes, o que garante que as informações certas no formulário correto estejam disponíveis para a pessoa certa no momento certo. O sistema resultará em um trabalho mais rápido, menos erros e um fluxo de trabalho mais suave para uma organização.

Palavras-chave
Industry 4.0, LIMS

Abstract

The World Wide Web not only changes the process but also improves the user experience. Also, it dramatically changes how the computer software is built. This profound evolution of software development has caused developers in the software industry to change their way of developing software. In this project, the Laboratory Information Management System (LIMS) for Staff and Users of small business have been designed and developed using Throwaway Prototyping methodology with the web architecture.

Different types of development platforms are available in the market to develop this application, but as per the company requirements, this application was developed with the .net framework. This web application allows us to access application data on different devices like a tablet, a desktop, a smartphone from the remote location all over the world. The main feature of this application offers to monitor the application activity like which activity was performed by the user with the corresponding date, time and short description.

Therefore, this software uses an industry standard relational database management system (RDBMS) combined with a platform-independent web browser interface for data entry and the retrieval. (The 3-tier technology)

The laboratory workflow steps facilitate the management and tracking of all test and test results, which ensures that the right information is available at the right time to a right person. This system will produce an efficient process in the laboratory which leads to faster work, fewer errors, and smoother workflow for an organization.

Keywords

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Acronyms List

ASP	Active Server Page
BI	Business Intelligence
CIMS	Computer Integrated Manufacturing System
CMS	Content Management System
CSS	Cascading Style Sheet
CSV	Comma-Separated Values
DBMS	Database Management System
EEC	European Economic Community
ER	Entity-Relationship Model
FTP	File Transfer Protocol
GUI	Graphical User Interface
HTML	Hyper Text Markup Language
HTTP	Hyper Text Terminal Protocol
I4.0	Industry 4.0
IIS	Internet Information Services
ISAPI	Internet Server Application Program Interface
ISO	International Organization for Standardization
IT	Information Technology
JQuery	JavaScript Query
JS	JavaScript
LAN	Local Area Network
LIMS	Laboratory Information Management System
MES	Manufacturing Execution System
NOS	Network Operating System
OODB	Object-Oriented Database
OS	Operating System
PC	Personal Computer
PDF	Portable Document Format
QA	Quality Assurance

QC	Quality Control
RDB	Relational Database
RDBMS	Relational Database Management System
SLIMS	Sample-based Laboratory Information Management Systems
SME	Small-to-Medium Sized Enterprises
SOTA	State of the Art
SQC	Statistical Quality Control
SQL	Structured Query Language
UC	Use Case
UI	User Interface
URL	Uniform Resource Locator
UX	User Experience
VB	Visual Basic
VS	Visual Studio
WIP	Work-in-Process
WWW	World Wide Web
XHTML	Extensible Hypertext Markup Language
XML	Extensible Markup Language

1. Introduction

This chapter explains the task given for the master thesis Laboratory Information Management System in the second year of the Master in Applied Informatics at School of Management and Technology of Oliveira do Hospital - Polytechnic Institute of Coimbra. It also includes the task description and background with the aim and scope of the work. Furthermore, it consists of an explanation of different chapters in the report.

This chapter will elaborate on the purpose of the thesis. Firstly, the motivation of the thesis is presented, and the reason behind this research is described. Then, the current issues, as well as the problem statement is presented about the LIMS concerning the software available from the vendors in the market makes the relevance of researching the topic evident. Further, the background of LIMS is explained brief along with the task description of the internship report.

1.1. Motivation

There are varieties of LIMS applications available in the market with advanced features which helps in laboratory data management. The software available in the market comes with general features. However, not all features are useful for the small laboratories. Also, it makes an application more massive, costly and takes more time to develop. It is not affordable for small businesses, and due to this reason, small organizations work with excel spreadsheet and papers, which is time-consuming process and also, it is difficult to generate reports by collecting information from the different places, print it and send it to the clients make the process more expensive. Nowadays, laboratories are improving and managing data in a smart and easy way. There are some laboratories which are working on their ideas, and they have their requirements for software development to manage their data and information. In order to save time and cost, we have developed this small LIMS application which could be very beneficial for the small businesses because it's simple, light weight, powerful and it took less time to build the application, which makes it less costly. The main reason behind the small organizations not purchasing the customized LIMS application from the software vendors is because they are very expensive and instead they manage data on an electronic spreadsheet [1].

1.2. Problem Statement

One of the significant problems associated with the organizations related with LIMS software is the presence of multiple vendors in the market and subsequently it becomes difficult to select or choose products from them. Many vendors offer products and services that are not compatible with other similar product from the same domain.

Since last few years, we have seen significant growth in usage of tablets and smartphones in information management. Currently, many people are working remotely and encourage doing so by their employee. Therefore, LIMS software needs to be the cloud-based and with responsive design. In order to develop software with these features, it requires a significant amount of time, dedication, and money. If we make the wrong choice for some section, it could result in a failed project [2] [3].

Also, it requires to choose the best language to develop LIMS software available with useful features to build a good LIMS software with the best security features as per the requirement. The primary goal of this thesis is to develop a LIMS application for the small laboratories which are still not using any software to manage their laboratory data and using obsolete techniques by filling up the forms for samples, test and writing reports on papers.

1.3. Task Description and Background

Laboratory Information Management Systems (LIMS) is essential for management of laboratory data storage, tracking and reporting of laboratory processes. As per the market research conducted by Illumina[1], the latest LIMS applications assist in checking the quality of lab experiment, result, and status of an organization.

LIMS application stores laboratory data permanently in a structured format in a relational database for data validation and facilitates automated analyses. The permanently stored data helps users to analyze data and present the overall report for a specific year. Large research organizations often have very complex requirements that may change over time as per the project requirements. The customization of LIMS software enabled to store and display data for a different project can result in being expensive [4]. The developed LIMS software is enabled to customize test, result module, and display rapidly the results. It also enables the laboratory to build a modular LIMS and web-forms to capture the data inserted by the user and display it into an appropriate place in the software.

We have used Standardized Query Language (SQL) database to design schema to create a user interface. It also provides standard features such as searching data in the database tables, data filtering, and sorting; that can be essential for navigation in the volumes of data. There is a new designed feature available in our LIMS software, i.e., users can design a dynamic test form providing fields with validation. The developed LIMS software allows the user to design a dynamic test form with different criteria's (which we will explain in another chapter of this thesis). The test result will validate inserted data with provided criteria which while inserted at the time of designing a test form, gives an alert to the user. And these results do not match the appropriate criteria. Also, criteria will display in a dynamically generated report with the text like; test result is appropriate or inappropriate. This way we try to serve a better solution with limited features and lower the cost of software for small laboratories [4].

1.4. Aims of this project

Despite commercial LIMS software available in the market, some laboratories prefer getting their reports in paper and excel spreadsheets. It is hard to manage laboratory data, and this method is time-consuming. In the market research of LIMS software, we have noticed that the software vendors try to accommodate all that features which cover multiple laboratories with different products, and it is complicated to manage different products in one software. Also, client requirements are changing rapidly and therefore, customization is required in LIMS software. By keeping this thing in mind, we have designed and developed a web-based LIMS software to manage small laboratory data like add sample, test and generate dynamic reports for the added test result. It is required to present data differently to analyze a lab report efficiently, and a current market trend is to present data in a chart view or with designs to analyze the vast amount of data in an accessible way. Also, using drop-down menu filter data, we can dynamically present data into the chart form.

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[1] Adapted from Illumina - https://www.illumina.com/

1.5. Project Definition Discussion

Initially, we decided to research about Industry 4.0 and develop the project for a small laboratory. In industry 4.0, we have discussed the mobile-friendly design and cloud-based web application which can be seen below in Figure 1.1. Therefore, we can access this application from anywhere and anytime whenever required.
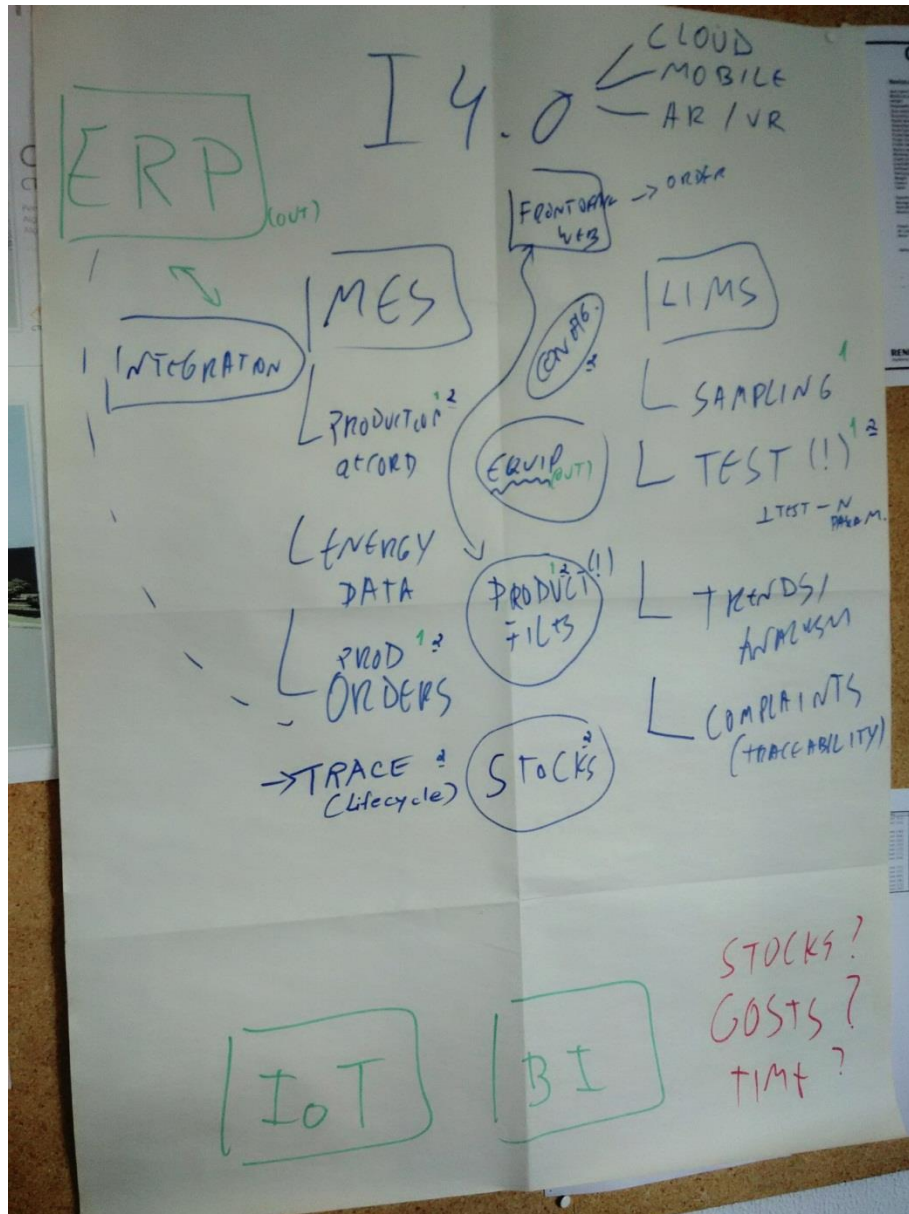
Figure 1. 1 Project Definition Discussion

1.6. Project Workflow Discussion

Figure 1.2 summarizes the workflow of our LIMS web application. As the first step, the user can fill out the form and insert sample information. Once the sample data is inserted, the system will redirect to the "apply test page." and this page will display a list of all samples and test, from where a user can select a sample and apply a particular test on it.
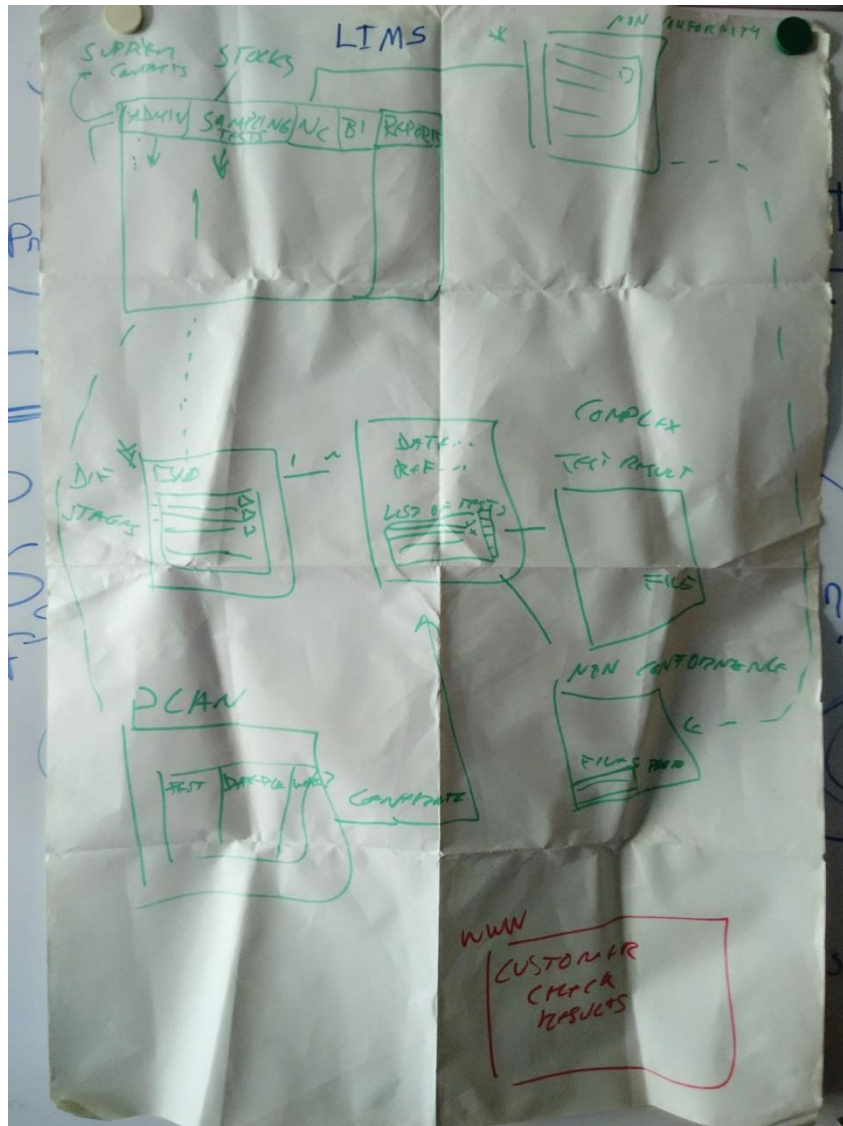
Figure 1. 2 Project Workflow Discussion

From the list of an applied test; a user can add result for a test of a particular sample or can delete the applied test too. Also, a user can add more than one result for a single test. Finally, a user can see all the test results in list view and can download the results in Portable Document Format (PDF) format.

1.7. Structure of the Report

The internship report is split into seven chapters and are presented briefly below:

Chapter 1: Introduction

The introductory section describes the objectives of the thesis, the scope of each task and the structure of the report.

Chapter 2: About LIMS

This chapter introduces the LIMS application.

Chapter 3: State of The Art

This chapter explains types of LIMS available in the market and at the end a summary.

Chapter 4: Planning

Project planning is an essential part of new project development as it helps the developer to identify the necessary resources to fulfil project requirements and accomplish a goal within the available fixed timeframe.

Chapter 5: Objective and Methodologies

The objective is to transform the design into program and code modules. The final deliverables of the implementation phase are source code and related documents. The methodologies related to database design and database models. As per the task description, the database and scripts of Laboratory Information Management System should implement using SQL Server. Hence, a detailed study is carried out to understand and familiarize with the latest version of SQL Server and its tools.

Chapter 6: Developed Work

The developed work represents that what job has been done during the period of internship with detailed overview of the code and analysis of the results.

Chapter 7: Conclusions and future work

The conclusion represents the overall thesis result and what feature can be improved, afterwards illustrated as future work.

2. About LIMS

This chapter describes the literature within the research area involved in the internship objectives. The main aim is to provide the foundations and to introduce the scientific and the technical contributions proposed towards the field of laboratory information management systems. The first section of this chapter presents the introduction to LIMS software and corresponding benefits of using a LIMS solution. After that, the available LIMS that are sold in the market are presented with the critical view of the authors.

2.1. Introduction

A Laboratory Information Management System (LIMS) is a computer or computer network belonging to the class of application software system envisioned for the management and storage of raw data which is required for analytical purposes. In the initial development stages, it tracked the samples and tests performed in the analytical laboratories and enhanced the status of the samples and test results. Moreover, now, in the latest versions, the LIMS system is interfaced with the laboratory instrumentation and the subsequent communication networks that allows the complete automation of the data compilation, and generation of reports [5].

In the 1970s, the LIMS entered the market and became widespread as a consequence of U.S. Federal Government Regulations [6], [7], predominantly in the healthcare industry. The LIMS was viewed as a system to meet the governmental organizations' prerequisites for the laboratories which were participating in a Superfund program, to alleviate the design methods, and also impacted the further development in the use of LIMS system. In the early years, a LIMS was very costly and was altered for every establishment using the in-house personnel or a software vendor. More lately, around 40 vendors offering LIMS software have possessed the capacity to plan the frameworks with enough capabilities to address the issues of most research laboratories [8]. The commercial systems can be delivered economically and rapidly, and the research facilities can benefit from the large user base with the compatible accessories and the future improvements in the systems [6].

The advantages of LIMS generally rely on the necessities of the research facility and the type system available in the work environment. In all, a LIMS enhances the administration of the research facility by providing more exact information with time convenience, with respect to the remaining task at hand and the outstanding task in the organization. The efficiency expanded through the timely automatized solution in regards to the routine tasks accompanied by the identification of samples, data tracking and the records of the results [9]. The nature and the quality of information can be further enhanced through automated data acquisitions, decrease in transcript errors, interpretation blunders, and the automatic enhancement of the validation analyses and also, the standardization techniques. At last, the system would be able to utilize to meet the governmental organizations' compliance conditions.

2.2. LIMS Function

A LIMS is a database management tool developed to assist research laboratories, mostly the scientific laboratories, and to manage the data gathered in the facility. The LIMS database typically incorporates the biographical information about the samples, for example, the source of the sample selected, the client, the project or the charge number, and furthermore, the interpretations of the results. Also, a critical factor involved in the LIMS function is to provide information online regarding the sample's status. This data can provide the researchers with the identification of the sample's location, the state in which the appropriate analysis is performed, and the completion of results, if any. A LIMS is valued the most when various or most consecutive

analyses are performed on one or a progression of tests. A LIMS system can produce multiple requirements and have the samples spilt and sent to the suitable research facility. This system would then be able to utilize to form a single report for the client. According to [4], the LIMS functions can be categorized into analytical or managerial tasks, and Figure 2.1 illustrates the typical flow of a sample entering the laboratory. The dealers or suppliers of LIMS comprises of Banyon Systems Inc., Beckman Instruments Inc., Challenger Group Inc., Chesapeake Software Inc., Cirrus Technology, Digital Equipment Corp., DSP Development Corp., Hewlett-Packard, IBM, Keithley Instruments, Laboratory Data Systems Inc., LabWare Ltd., Northwest Analytical Inc., Novell Inc., PE Nelson Div., Radian Corp., Statistical Graphics Corp., 3Com Corp., Varian Associates Inc., and VG Instruments [10].

The LIMS functions is briefly outlined below:

   i.   Analytical Level Tasks-

- Sample Number Generation
- Barcode Label Generation
- Sample log-in
- Verification of data format entered into the system
- Worksheet Generation
- Data collection from analytical instruments
- Entry of instrumental readings
- Manual results entry
- Interpretation and acceptance of sample data
- Routine automatic calculations
- Plotting routines for visualization of analytical data

   ii.   Managerial Level Tasks-

- Acknowledgement of sample receipt
- Backlog investigation
- Sample and status tracking
- Database searches
- Number of samples assayed
- Tests utilized
- Number of samples analyzed per instruments
- Costs per assay
- Customer charges
- Result collation and presentation
- Report generation
- Scheduling and rescheduling of work
- Archiving and retrieval of data
- Workload status and the justification of equipment
- Regulatory agency compliance
- Audit trail for all database transactions
- Security, class or hierarchy
- Instrument records and calibrations where appropriate [11]

2.3. Automation

The advancement and broad utilization of PCs, tablets, smartphones, and the microprocessors in the research laboratory instruments have made it conceivable to totally automatize the laboratory, including the interfacing instruments specifically to a LIMS. In a completely mechanized

laboratory, a sample is logged into a LIMS system, at a point of exchange to the laboratory, where it is arranged for analysis or analyses, and later moved to auto sampler or analyzer. Once it is analyzed, the information is exchanged through a gadget which subsequently translates the raw data into information that a client requires. Furthermore, the interpreted data is reduced, and the LIMS further becomes a repository of information [12]. A schematic of fully automated LIMS is illustrated in Figure 2.1 below:
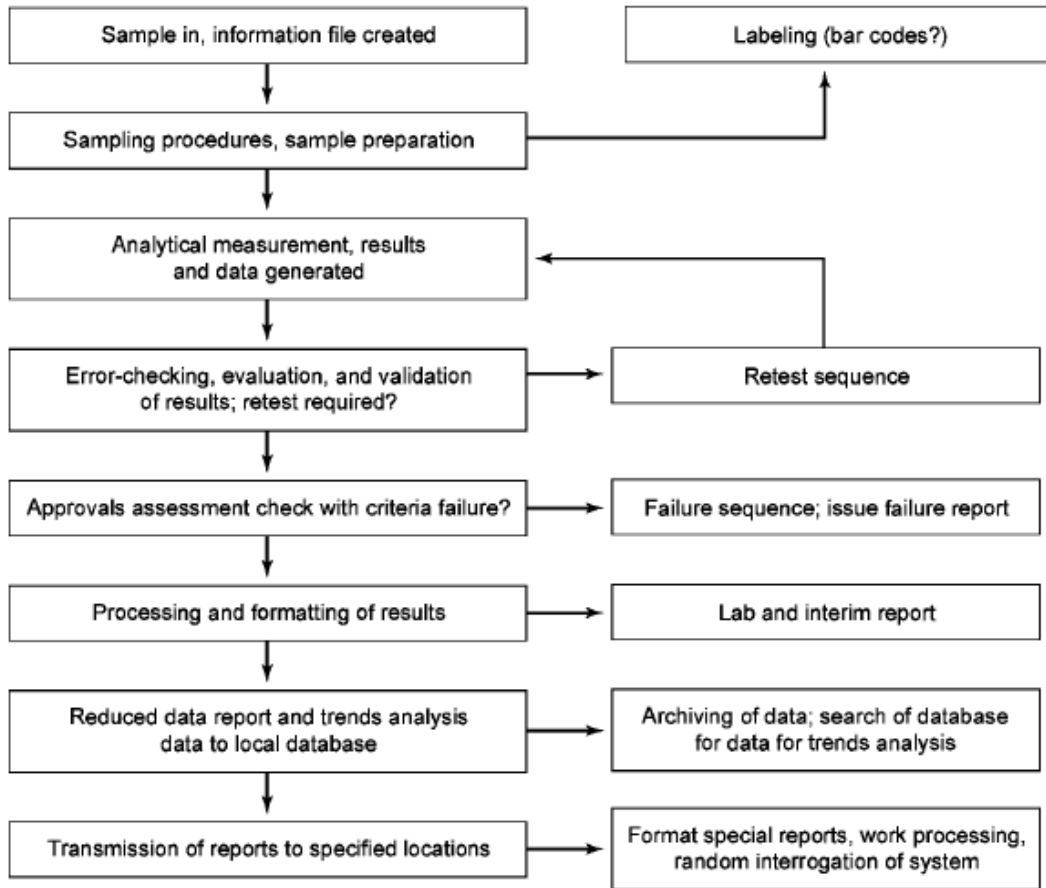
Figure 2. 1 LIMS Production Flowchart(Sample handling and reporting [13])

2.4. Quality Management

Any business activities of an organization require a high quality of data in the LIMS system. The security and administrative prerequisites for LIMS information data characterize the level of exertion used to approve a LIMS and the information being put away in the storage. Additionally, the nature of the equipment and the programming used to actualize the LIMS both assume a part in characterizing in general system quality [14].

In LIMS, the quality of data plays a vital role as in terms of association with the system in the business organization. In an R&D domain, for instance, the underlying explanation behind a LIMS maybe to compare and diagnosis of a new analytical method [15].

Most often, the manufacturing organizations actualize the LIMS system for their Quality Assurance and Quality Control (QC) in their facilities. These facilities guarantee that the product manufactured in their facility of high quality, and inspects intermediaries to keep up the production work on time in right quantities. Statistical Quality Control (SQC) uses techniques such as Shewhart control charts, Pareto charts, and time-to-failure (Weibull) analysis [16]. These

research laboratories ensure that it incorporates features in order to avoid SQC limit violations and the trend violations. Subsequently, a LIMS can be used with Computer-Integrated-Manufacturing-Systems (CIMS) to address issues during the production process. Some LIMS systems have incorporated built-in statistical tools and other features that enable the user to export the data into other software packages for further analysis such as Excel spreadsheets [17].

2.5. LIMS Validation

The International Standards Organization 9000 (ISO 9000) standard, established by the European Economic Community (EEC), additionally impacts the manufacturers' implementation of LIMS systems. ISO 9000 is a set of standards which are required for manufacturers' selling products to the EEC. The ISO 9000 standards are credited with having an essential influence in the force to more prominent computerization and digitization of the research laboratory management of an organization [18].

A LIMS system must be approved and validated to ensure the safeguard of data security and integrity and to guarantee that it complies with the government agencies' regulations. The validation of LIMS incorporates the first developing strategy and setting up goals for proper validation of the entire system. Modular testing of the system must be utilized, and the nitty-gritty of test convention ought to be produced for each LIMS module [19].

The equipment used in the research facility; in terms of hardware and software, for the implementation of a LIMS system must be thoroughly validated. The networks, as well as the computer system, must be inspected for the potential threat of component failure on the LIMS information storage. Security concerns with respect to the access control to the LIMS information must be thoroughly addressed. The operating system (OS), the software, and the database management systems (DBMS) utilized in the execution and the implementation of the LIMS system must be reviewed and validated in order to protect from potential data loss and corruption. One such approach to such validation is to choose vendors whose products are recertified, but the LIMS validation remains the sole responsibility of the user. In order to validate the LIMS system, the required operation involves some amount of work, and the required infrastructure is a primary prerequisite for a dependable, flexible and robust LIMS system [20].

2.6. Cost and Benefits

The very first step in the acquisition of a LIMS is to justify a necessity for it. The expenses made to procure LIMS must deliver utmost value to the laboratory customers, while also delivering essential aids to the LIMS users and their management [10]. The organizational framework must be compliant with the operational changes that an acquisition of a LIMS will cause. If computer technology is not widely used in Small-to-Medium Enterprise (SME), it may be hard to mechanize laboratory functions. LIMS systems are dedicated information systems, custom-made to an existing outline of functions. If an information strategy has been defined for the organization, a LIMS can be defensible in terms of how it fits in with that strategy. If the organization has computing standards, the LIMS selected should follow those standards on every occasion possible.

Advantages of LIMS can be categorized into two phases: tangible and intangible. The tangible aspect being; it is easily assigned a monetary value. These include items such as a decrease in the expenses of calculating and reporting data, enhanced capacity through better access to management of data in making distributions, and being able to recognize and report sample status more quickly. The intangible aspects might incorporate better overall service to consumers and a general understanding of better laboratory management through the use of state-of-the-art

management techniques [11]. The table 2.1 below compiles the initial cost of LIMS and briefly describes the tactics associated with the cost of LIMS:

Category	Cost factor
Hardware	Computer storage devices; device cabling and wiring; wiring, power conditioning; climate control; furniture; networking; interfaces, servers, cabling, writing closets; user interaction; terminals, workstations; display devices; printers
Software	Operating system; system development tools; including communications and compliers; LIMS development tools; database systems and development tools; generic instrument interface software; special instrument interface software
Installation and Conversion	Personnel to manage acquisition and installation; disruption due to installation; loss of replaced incompletely depreciated equipment; lost space for computers, terminals, printers; customization and configuration; development of computer usage procedures, LIMS usage procedures, and new laboratory procedures; determination off-line vs on-line data needs; development of archiving and backup procedures
Training	Computer training for users, managers hardware engineers, support staff; LIMS training for users, managers, support personnel; instrument interface training for user, managers, hardware engineers, support staff; accessory software training for users, managers, support personnel; lost work during training
Configuration	Time to identify database form; time to set up system security, desired audit trails, and enter valid users; time to design and create necessary reports, charts, and alarms; time to configure laboratory for test, sample, instruments, projects, labs

Table 2. 1 Initial cost of LIMS categorization [7]

Another noteworthy advantage of a LIMS is the change of by and large, the nature of the research facility. If there should arise an occurrence of a research center, where quality is characterized as a fulfilled client needs in the territory of precision, dependability, lucidity, and auspiciousness of logical data. LIMS can upgrade quality in number of courses, for instance, in checking conformance with the prerequisites, in sorting out and organizing work to guarantee auspiciousness, in estimating research facility execution in zones of specialized quality and productivity in order to give constant change, and in helping the lab to impart plainly, totally and reliably [21]. The table depicts the benefits of LIMS as shown below:

Category	Benefit factor
Data management	Data may be stored more systemically, more data conveniently stored prevent; track a greater number and more complex relationships; change data more quickly; data may be more secure; security can be more highly tailored and may be more secure; security can be more highly tailored and may require less managerial oversight; audit trails can be automated; transactions are more traceable; managerial information on the amount and type of data are improved; data can be recalled more quickly and flexible; improved reliability of data stored and retrieval; data may be handled more flexible; reporting is faster, unit printing cost and cost of transferring data may be reduced; new relationships among data are more easily examined; data are available when needed by requiring its entry
Laboratory throughput	Entry of sample information and sample identification may be faster, reduced transcription (offset by possible increased data entry time); faster Quality Assurance/Quality or Statistical Process Control; speed of analysis; automation of entire analysis; faster response to queries; faster and automated reporting; automatic validation of results; inspection only of discrepancies; assistance in remembering procedures, prompt for required data
Quality of data	More accurate data because of automated acquisition and range checking; more accurate sample identification due to bar codes; reduced transcription errors; improved instrumentation reliability from Quality Control and automated calibration procedures; more involved Quality Control procedures; Statistical Process Control on laboratory analyses; automatic enforcement of validation procedures, laboratory analysis procedures, and instrument standardization procedures; automation prompt for missing data
Laboratory management	Improved accuracy of laboratory management information increased quantity of laboratory management information; reduced labor to produce laboratory management information; more instruments, analysts, results handled per manager, reduction in lost opportunities due to inadequate knowledge and in unsolved backlog problems; improved validation procedures
Quality of operations	Statistical Process Control on manufactured products; reduced testing costs; corporate Computer Integrated Manufacturing system; improved Quality Assurance/Quality Control on products; reduced testing costs; correlate laboratory analyses and process measurements; faster solutions to production problem tested in laboratory; faster notification of backlog problem, improved electronic data interchange capabilities; automated communication with inventory, ordering, and materials planning systems
Regulatory compliance	Automated regulatory report generation;; regulation-complaint audit; enforce regulation-complaint laboratory procedures and results validation; improved response to changing regulations; fast compliance with regulatory audits

Table 2. 2 LIMS Benefits [16]

2.7. Selection of LIMS

Before selecting a LIMS product, an entire set of specifications for the desired functions of the LIMS ought to be written. The most effective time to try and do this before any vendors are contacted. Inviting vendors to participate during this method ends up in a specification which might be mechanically consummated by their product. An intensive understanding of current information management processes is critical to draw up a specification [22], and vendors do not possess it.

Whilst researching the necessities for a LIMS, answers to the following questions need to seek [23]. Is the laboratory to be used for a single method or more than one method, for a single product line or product type, or for all sorts of samples? Would a remodel of experimental strategies yield an increase in productivity? Are there management necessities, including clerical support? Are computing resources mandatory, including a laboratory management data system, local data collection, and storage of instrument results, data storage, and filing necessities at the laboratory level, use of workstations, the introduction of local area networks (LANs), workstation interfaces, and telecommunication facilities? Are there reporting, archiving, and database requirements? Are staffs archives to be involved in the computerized laboratory management scheme? What overall response and speed of the system is required for the turnaround predictable? What is to be done about the training for the users, a most important obligation that is easily overlooked in the development stages?

The pursuit for the vendor can commence once the requirement is complete. The level to which a vendor's products fit in with built up necessities is the most critical choice basis for a LIMS. Financial dependability of the vendor association is another thought as a result of continuous specialized help from the seller is fundamental to LIMS execution and improvements [19]. The technology utilized in a vendor's products ought to be assessed for robustness and durability. For instance, a merchant with programming items composed for about out of date processing stages would not be a key decision. Counseling administrations offered by a seller can be significant for actualizing and keeping up a LIMS. For instance, a vendor with software products written for outdated computing platforms would not be a key decision. Consultation services offered by a vendor can be an added advantage for implementing and maintaining LIMS.

Once the necessity for the LIMS has been justified, specifications are written, and accessible vendors gaged, the LIMS selection process begins. Each vendor's product should be evaluated for conformance to the specification and flexibility for future changes. If an adequate solution is not available commercially, consideration must be given to constructing a customized LIMS solution. This could be done in-house or by contractors. If the customized option is favored, the resources needed for future changes and maintenance should be factored into the cost [17].

Selection of LIMS software should deliberate both data compatibility and usability. Since a LIMS is one information system within an organization, it may need to share data with other systems. Therefore, the software should be capable of sharing records without delay or exporting data into compatible formats.

2.8. Database Management

Most LIMS systems use a Database Management System (DBMS) for storing data. Examples of commercially available DBMS are DB2, DBASE, Informix, INGRES, ORACLE, and RDB. All of this, DBMS conform to the "relational" model developed by Codd [13].

Relational Databases can keep an infinite number of results for every pattern and limitless samples for every request. The gain of a relational DBMS over a greater conventional hierarchal device, wherein records units may contain other information sets, is that the layout of the database only must recall relationships among data elements, now not the range of times for any given variable.

A DBMS performs what's known as a transaction control. This process allows multiple customers to access and store data inside the database without corruption. The ability to do this is essential, when data is being written to the DBMS because energy interruptions or hardware failure can motive database transactions to be incompletely treated. Transactions managers use the "all or not anything" principle; all the statistics are written to DBMS, i.e., the transaction is completed, or none of its written.

Another vital function of a LIMS DBMS is the ability to perform ad-hoc database queries. It is not possible to expect all the forms wherein LIMS users will need to show their data while the LIMS is being designed. As an end result, it is far ideal to choose a LIMS which allows users to define their reports. Most commercial DBMS have a standardized query language (SQL) interface. SQL is a simple database query device that's primarily based on English language instructions. This sample SQL query says, "Get all sample requests information containing Richard Dawkins as the customer." [9]

2.9. Impacts of New Technology in LIMS

The costs of computer hardware have diminished significantly over the years. As a result, the computer system has become more affordable in general. The higher execution of innovation enables more practical ability to be given in a littler, more affordable machines.

Advances in the network operating systems (NOS) give database server and independent, concurrent (shared) data processing capacities required to help LIMS functions throughout a network of computers. Beforehand this was conceivable just with an incorporated handling model, for example, in customary minicomputers and centralized servers. The cooperative network model, also known as peer-to-peer processing, utilizes a network to distribute data and processing. This permit building of systems that can be extended as needed. The independence of each machine eradicates glitches intrinsic in the centralized model, such as the high point of failure, and high startup and maintenance costs. Peer-to-peer networks were believed to be easier to maintain and operate. This isn't in really obvious, on account of appropriation of information required for autonomy powers systems to store information incidentally and forward it to a central location to permit access by other system nodes. Accordingly, not all information is accessible in one place at one time, making effective organization troublesome for everything except little, very customized systems [21].

Another noteworthy effect of new technology is the development of the client/server computing model into commercially feasible systems. This model integrates a more powerful computer for data storage and recovery (the server), linked to the client workstations via a network. Client computers accomplish dealing out for the user interface and authorize communication and data to the server. Consumers are predominantly personal computers or other graphics-capable devices (such as windows terminal). Under this model, processing can be dispersed within a highly unified, secure data storage environment. Client/server designs accomplish a system which delivers the individuality of the obliging network (peer-to-peer) computing model, but it is highly accessible, safe, vigorous, and easily managed. It has the added benefit of offering a graphic user interface (GUI) to the LIMS users, in which computers, file systems, and programs are categorized by simple icons, provided that a accustomed environment while hiding network and server intricacies [17].

The Client/server model often lets informal incorporation with other network applications (e.g., finance, project management, or human resources) which characteristically function in the environment of the server component of the client/server system. Client/server can be progressively familiarized in an existing minicomputer environment, often with little adverse incremental influence in terms of reskilling and extra expenses [21].

PC workstations have become powerful, are simpler to use, and are normally pervasive within both office and laboratory environments. Using Windows-based as well as Mac-OS based software now widely available on instrument data stations as a basis for the LIMS will lessen the training expenses and investment necessities when executing a LIMS [24].

Networks essential for peer-to-peer LANs often now occurs in some form because of other office integration efforts. The presence of these networks can often cut LIMS implementation costs by taking benefit of the reusability of the systems and networks already existing in the laboratory [19].

Databases are becoming more consistent, thereby letting a greater number of additional functions to be added to a LIMS and foreign systems, e.g., project accounting, to be easily unified. For these reasons, the desktop and client/server models are predictable to growth in the proportion of LIMS software contributions and installation base in the future [25].

Instrumentation developments have enlarged the power and quality of the fundamental analytical techniques used in aggregation with LIMS. These developments come at a cost of cumulative intricacy and volume of information [26]. Despite all of the architectural and technological developments of computer hardware and software, the demands of the information necessities still exceed the computing competences, so as to put ongoing pressure on computer manufacturers to escalation of storage and processing proficiencies even further.

Modern analytical instruments are inclining towards results which cannot be compact to the single-valued outcomes easily entered in LIMS. Many of the newer instruments yield enormously multifaceted results in the form of tables, spectra, images, or multi-dimensional associations which are not easily signified in databases using the relational model employed by most existing LIMS [25]. Existing choices range from using non-numeric completion characteristic, which might reference a secondary computer file containing the multifaceted results (this file may or may not exist on the same computer as LIMS), to an substitute which treats the multifaceted result as single objects and moves to the use of object-oriented database tools to accomplish the anticipated information within the LIMS itself [17]. Shorter-term incorporation with present file and document management systems may be used to simulate the object-oriented database (OODB) perception.

Data acquisition has progressed, but standards are still deficient [11]. This makes data acquisition the most problematic and time-consuming feature of the global LIMS implementation. The time savings which result from the automated data capture outcome in its normally being assumed, to some degree, notwithstanding the difficulties. Other than chromatography laboratories and others which have more even instrumentation environment, the data acquisition percentage of the LIMS implementation inclines to be a custom integration development project. This results in a comparatively fixed system which can be unfavorably affected by deviations (upgrades) to fundamental analytical subsystems [21].

Effort is being done to create uniform standards for exchange of information between analytical instruments and external (host) computers, but the multiplicity and the competitive nature of the instrumentation market incline to hinder these efforts, leading to an environment of continuous changes and an essential need for new and unwritten programs to connect between LIMS and the automated instruments [23].

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2.10. Main benefits of using LIMS

A LIMS provides a different type of users of a laboratory. The following is the outline of several main benefits identified and realized from current LIMS: [27] [28]

2.10.1. Efficiency

Enter Data Once

The user enters the data for product, client, sample, and the test can be used for reports and data exports. It does not require to insert again to generate reports

Retrieve Data Quickly

The process of retrieval of information from the bunch of data is easy and simple by using different queries, which makes the application more reliable and flexible.

Generate and Send Reports

The process of generating fast and dynamic reports has become easy and it can also send directly to the client. The dynamic generation of report provides more accuracy of the laboratory data.

2.10.2. Productivity

Increase Throughput

It is accessible to analyze the sample and track the records of laboratory data. Moreover, the laboratory does not require any more employee to manage this kind of stuff. Also, the system gives the more accurate report than handmade calculation

Track Productivity

Generally, all laboratory information management system provides information about the client, product, sample, and test. Moreover, we can keep track of which is the upcoming sample test, which is going to expire and which is already expired

Spend Time Effectively

This application is a time-saving application which allows a user to work without paper handling task and generate reports dynamically. Previously or even currently, some laboratories are working with spreadsheets to manage their laboratories data. It is challenging to manage laboratories data with the spreadsheet and reporting on papers. The spreadsheet provides filtering but still it is difficult to maintain data and generate reports. In order to manipulate data, the user needs to find or collect it from different places where LIMS software can manage it automatically. By using LIMS, software user can solve out this problem very quickly, and it is the time-consuming system.

Document Lab Output

There is no need to give more efforts to finish tasks. LIMS software increases organizations' productivity and documentation level without giving efforts.

2.10.3. Accuracy

Reduce Error

The LIMS application significantly reduces error, because of the limitation of manual data entry and the user needs to select primary things from the drop-down and menus. The LIMS software system can collect information fast and in an easy way. Besides, working with this software, the user can create their workflow and reduce long and repetitive manual processing and enhance efficiency

Verify Data at Input

Nowadays, the system has become smarter and the user can enter data and system will verify some of the fields as per the validation and allows it to insert into the database.

Avoid Missing Deadlines

The LIMS application displays the upcoming samples on the dashboard and also list out that samples which are already missed deadlines by comparing dates.

Avoid Embarrassment of False Results

The LIMS system generates the automated result by fetching data from the database related sample, which may help to avoid the embarrassment of having false results.

2.10.4. Security

Establish Secured Access

If we talk about security, LIMS will protect data by providing a different level of users. Using this feature, the system separates features as per the user level and provides access. For the security purpose, the system provides the user level permissions.

Track Database Revision

Current LIMS software can track sample and test data automatically and manage the laboratory information in an effortless way. By using tracking feature, the system can provide laboratory information for an appropriate time. The system can provide delay information, upcoming sample and test information using these features below

- Client Satisfaction

- Configure Reports to Meet Customer Needs

- The LIMS system generates automate

- Invoice Customers Reports Are Available

LIMS software generate reports automatically daily. Also, because the system is dynamic, it fetches data dynamically from the database and gets the reports without any errors. This way we can say current LIMS can provide daily basis error-free reports.

2.11. Summary

The Internet has allowed the access to information, expediting business transactions, communications, online shopping, online banking. In short, an internet provides the effortless way to save time without giving efforts. In this way, we should take benefit of the laboratory information management system. The LIMS software follows the structure and LIMS's flow is like a sample and then associated with the test data and gives the result of a particular sample. And laboratories can transform data into information, and that can be used to make a critical business decision. Modern LIMS provide self-audition capabilities and easy access to previous data through different queries and reports. Initially, we are going to explore the general benefits of web-based application compared with a traditional software application and then describe how efficiencies can be achieved today through the implementation of an entirely web-based system.

3. State of The Art

This chapter explains types of LIMS available in the market and at the end summary is presented.

3.1. Types of available LIMS solution

Different laboratories use different types of software system during laboratory operations. Also, requirement changes rapidly as per the requirement. Because of this reason, it is required to take a decision that laboratory needs to buy software or build own software before implementing the LIMS software for data management and practical decision on the downstream success of the software. It is important to note that there is no answer to this question that; Should we buy software from the market or build own software as per the requirement. Keeping this thing in mind, whether we should purchase an existing software in the market, develop own software with in-house resources or make a contract with a software development company to build the system for our laboratory.

3.1.1. Custom Development LIMS

The laboratory needs to be up-to-date because the customer requirements are changing rapidly, which does not meet with any of the commercial LIMS software's availability in the market. Generally, this results in the decision to develop a custom laboratory software application tailored to execute the custom LIMS software. The organization requires to hire a software development company to develop custom LIMS, which collect laboratory information and develop LIMS software as per the laboratory needs.

In general, customized software is providing more features like without the use of a handwritten code, in comparison with other software's, but this process is costly and not affordable for all laboratory. It is complicated to achieve goals without making any modification in software. The user can access this code in two ways; the first one is adding user hand-written code or customization in one of the standard LIMS functions. In an entirely hand-written code, a user can insert a new LIMS menu which looks like a standard function. This customization feature allows the user to add, edit and delete this menu anytime whenever it requires. However, this feature is added to the user hand-written programs as menu item certainly provides endless customization. [29].

User Event Routine

User Event Routines are associated with LIMS functions. Some menus and features are as following, in which User Event Routine can be added [29]:

Admin Menu

Admin menu can Create, Edit, Delete Client Information, Project Information, Subject Information, Schedule Information.

Sample Menu

The sample menu can create log sample, create new sample collection, receive sample information from sample or collection list, and generate new worksheet. Also, this menu can modify sample information like edit sample information, cancel sample and test requires.

Result Menu

This menu can enter or edit test result or review test by sample, test or worksheet. Approve samples for a subject and by the individual sample.

Lab Setup Menu

Using this menu, the user can gather information, divide information, instrument type information, location information, route information, ID, log information.

Report

By using this report menu user can print sample label.

System Menu

Using this menu, we can insert or edit user information; menu or function also can edit the parameter information.

Archive Menu

Used to archive sample data, retrieve data from an archive or copy LIMS data to retrieve database.

As above mention LIMS function is available in customized LIMS, which is quite expensive. Each of this function has unique functionality and a unique name assigned. Following are some different methods, which is called by user event routine.

- Pre-Commit: This method is called after information filled out on screen but before committing to the database.
- Post Commit: This method is called after committing to the database.
- Function Exit: This method is called after the LIMS function exists.

User Action Routing

Digital Management System is used to design LIMS user interface. Which is digital layered product and provides a user interface to the LIMS application. LIMS application is used more than one forms and each form has several desire parameters. User action routine is a user-written subroutine, which is called much earlier time when the form is displayed. Different field has several parameters, which are associated with each field. This field parameters include the field name, text for help, validation for numeric and alphabets, display reserve videos [29].

Data Reduce Algorithm

These algorithms are a user-written function, which uses to enter or change a test result and defined to LIMS conjunction with the specific edit test or insert. The concept of a specific test is a combination of three components test code, sample type, and test limit type. The test requires because of different sample types. Data reduce algorithm is used in conjunction with three LIMS enter or edit result functions. These three functions enter or edit test results by sample, test code, and worksheet. Whenever the result is entered or change, enter or change; that time test result calls appropriate data reduction algorithm. This algorithm is used to calculate a result from

intermediate results, raw data or test component values. The test would enter some raw data then insert the final data and the result is calculated by this algorithm [29].

3.1.1.1. Advantages of Custom Developed LIMS

- The Custom development gives the exact result what they have asked by the client as per the requirement.
- The functionality has their property rights and proper control over the feature of the software.

3.1.1.2. Disadvantages of Custom Developed LIMS

- Generally, this type of custom LIMS software is very costly and project risk born by the laboratory.
- Project development is very slow initially.
- The software development cost hundred percent worth.
- The laboratory also provided support of infrastructure from the software development company.

3.1.1.3. In-house Developed LIMS

Generally, Laboratories comes with the option of the elimination process. The number of products is used for testing which precisely does not meet laboratories requirements. Still, internally, development is going on by many organizations, and it can take lot of time, resources, in additional facing more problems for implementation. The negative perception is that many laboratories cut off the substantial benefits that well developed and installed LIMS can bring to a laboratory. Drastic reduction of the spreadsheet, paperwork, and improvement of data recording, taking to the efficiency and increased quality of result reports and analytical reports are the main benefits of LIMS software. Many software's are developed just for specialists of their laboratories. Current LIMS software helps to improve and enhance laboratories practices. Future LIMS can implement with knowledge-based systems with the global access of the laboratories data.

3.1.1.4. Advantages of In-house LIMS

- The in-house development provides vital features as per the requirements.
- The software could be developed without paying high budget for custom development.
- No learning process for the laboratories employees' because they are familiar with the laboratory's requirements.

3.1.1.5. Disadvantages of In-house LIMS [30]

- Software development may not sound perfect as they are developed by the professional programmers
- The programmer can leave resulting in unpatented products.
- Laboratories can reduce one staff member who is developing this software.

3.1.2. Commercial LIMS

The reputed vendor has already developed the software, which is available in the market. Laboratories have the bunch of data with the high data flow, which needs to organize. This challenge responded by automated instrumentation. Some market software still uses different data formats and software interfaces. Data management system introduced to manage and handle the laboratories data. In the earlier time, these systems were the one of the best solutions designed and developed by software companies to run in specific laboratories. These difficulties increase while they were electronically allowing large data transaction. Same time, system solution provider developed a customized LIMS and provided a commercial LIMS product, and use of commercial LIMS been raised and laboratories are moving more and more to the small workstation and started buying their system at laboratories. In the current generation, LIMS become globally recognized, and LIMS is providing more solution from the commercial software for the laboratories and vendors become available who is providing the LIMS solution. Today, more than one solution software is available in the market with the capability to fulfill the specific requirement with the standard solution with the accessible user interface. Additional, LIMS are using open source platforms to offer client-server-based application software. Some failed, just because of this negative perception, this commercial LIMS becomes less useful to the medium to small size organizations [31] [32] [33].

3.1.2.1. Advantages of Commercial LIMS

The commercial LIMS comes with several benefits compared with different types of LIMS, i.e., custom developed and in-house developed laboratory management system. The main benefits of commercial LIMS are:

- Best practice development
- Fast development
- Market Competitive & Cost sharing by Clients
- Easy Access
- Technical Support 24/7

3.1.2.2. Disadvantages of Commercial LIMS

There are also some disadvantages of commercial LIMS like mentioned below:

- Customization requires as per client requirement
- Helpless Product Features

3.2. Market Software

After some research and comparing requirements for small laboratory; we found following two software's available in the market; named Lab Collector[2] and Sample-based Laboratory Information Management Systems (SLIMS)[3]; which are capable of extensive and provide full

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[2] LabCollector Website - https://labcollector.com/

[3] SLIMS Website - https://www.genohm.com/

customization without any kind change in code or informatics knowledge. The customizable feature of this software offers to configure to match own laboratory process features and procedure. We have used this software features to compare with our software features and explained that is why our LIMS software is different from the market software and how it will be beneficial for the small laboratory.

3.2.1. LabCollector

A good laboratory information management system requires a good software application. For modern laboratory, LabCollector is such a good LIMS software, which is available in the market. LabCollector is an AgileBio product, which is a web-based application, it means this software can be accessed through the internet on a web browser. There is only one single computer that works as an administrator in a laboratory, who have access to manage all features of LIMS application and can assign different roles to other users, it means this admin computer works like a server. This LabCollector is a web-based system, and there is no need to install extra software to configure this LIMS application, and this application is a lightweight application. It is cross-platform, so it becomes effortless to install different operating systems like Windows, MAC, Linux. LabCollector can be accessible from all computers, which is connected to the same network. It is also possible to access in other computer systems using the internet, because of this reason LabCollector is protected using the password. The user interfaces of LabCollector is accessible through the simple computer browser like Chrome, Firefox, and Safari. Therefore, using the LabCollector; a user can access the lab's data remotely. Even LabCollector can access through the wireless device. The LabCollector also provides more features like an update as per the new software available on the market, backup of whole laboratory data and migration of the database [34].

LabCollector Solutions

LabCollector supports industries like Bio Academic R&D, forensic, Biotechnology R&D, Agri-Food, Beverages, Clinical trials, Cosmetology as a laboratory solution.

Advantages of LabCollector

We can configure new, different users with different accesses. The primary user is the "Super Administrator," and this user has full powers to make changes within all the LabCollector. Super-administrator can define one group to manage a user's general permissions. It blocks the user after three failed login attempts; only super-administrator has access to unlock it. They provide two password encryption methods legacy or SHA-256 for different level security purpose. A user can set a proxy to take benefits of external tools such as RSS feeds. Task scheduling to send an email with electronic import data. The system is allowing to setup own SMTP email server to send an email. This software is also able to print barcode labels. LabCollector application is available in different languages, and a user can set up a default language as per their requirement. Also, the search option is available to search data from the database, and a user can create indexes to optimize searches. Using different modules, a user can export and print data. A log of user history is available to track the user actions, and a user can export it in excel format. LabCollector also provides sample management module; in this module, a user can insert one or list of samples at the same time, and create a category for samples. Address book feature is available to store our contacts in table format. Also, many more features are available in this software like seller management, bookmarks, software customization, and data analysis. A user can define storage for products into the system; also, we can create a box and rack with no grid to store the product information. A user can upgrade the software whenever updates are available. A user needs to upgrade it to take benefits of the latest features or to get rid of some issues which were solved by the vendor, or user can upgrade a system to use different features or upgrade system in a different

package which is available with different prices. The main advantage of this software is that we can get technical support anytime whenever required [34].

Disadvantages of LabCollector

The LabCollector has a super administrator user; it may reset the password and deliver a new password to the user. They have used google interface translator, which is translating everything using google translator; which sometimes provide incorrect translated sentence and make no sense or sometimes does not provide a proper translation. Sometimes, external add-ons are required to use some features. Customization is very useful, but it has more disadvantages like if we delete one field it will affect in the whole system and there is a chance to lose the data and get an error into the system and also, some names can include MySQL errors, which leads to the failure this software. They are providing different hosting platform like private, VPN, dedicated servers but there are different prices which user need to pay monthly and sometimes it is difficult for small laboratories. In this software, lots of features are available and sometimes it is not used by all laboratories which make this software or even database more substantial and make software slower [34] [35].

3.3. SLIMS

Sample-based Laboratory Information Management Systems which is abbreviated as SLIMS. The SLIMS is a web-based laboratory management system which is designed to integrate LIMS, Electronic notebook, and a Biobanking module. It provides customization and offers any user to configure a system to match their lab processes. As the complexity of modern since sample, test and data filter need modern digital management system; SLIMS can manage operations which deals with workflow management and other capabilities; which allows user full control over the process before sample shipped. SLIMS is flexible enough; so, the lab can develop own integration for their data management. It will enable a user to know real-time transactions. SLIMS supports MySQL, MariaDB, Microsoft SQL Server, and Oracle. Also, provide features like sample management, electronic lab notebook, permission management, and workflow management module. It allows a user to track sample and is fully customized by a user to meet the specific requirement of their laboratory. There is a global search option available to find secure way users' data. SLIMS has been designed to integrate an Electronic Laboratory Notebook (ELN), and it is more than just a notebook; a user can create standardized Operating Procedures (SOP) to share it with their colleagues. In addition, drag and drop feature is available, which comes under the latest trend; also, it personalizes laboratories workflow [36].

Advantages of SLIMS:

It is a web-based LIMS; we can use it from anywhere, from any browser. SLIMS can install on user's server, and a user can customize it to match their laboratory requirement. It allows a user to access an application from remote devices like iPad. Accurate localization features help us to categorize and filter samples easily. A sample can search by various parameters and also by scanning barcode. It supports text editor language and most language based on the Roman Latin alphabet. SLIMS can install, virtual or physical at our location on a server. Different databases are supported by this software like MySQL, MS SQL or Oracle database. Also, the back-end is available. Finally, this can generate reports. It provides two-way traceability to track relation between lab materials. SLIMS is suitable for any laboratory because of its customization features [36].

Disadvantages of SLIMS

SLIMS is only simplified on iPad app for the Electronic Laboratory Notebook (ELN) version. It is also available in a different language but to obtain it, the users need to contact the software vendor; the users are not able to change it themselves. Because of a large amount of data, software becomes heavy and difficult to manage; only the SLIMS engineers' team of Genohm can install SLIMS. The laboratory needs to call the vendor for customer service; without an engineer, it is difficult to maintain. It requires minimum configuration for software installation; without it, we cannot run it on any computer system. It is required to purchase a license per server, and the cost could be high. A different license is available with the various access level. Genohm releases about four significant updates per year and it requires up-to-date system to take benefits of the latest features. Because of many features, a user must require training to manage their laboratory data [36].

Table 3.1 summaries the comparison between different markets LIMS software in this table with own LIMS features.

Features	LabCollector	SLIMS	Own LIMS
Developed By	AGILAB	GENOHM SA	
Applied to all research related	Life Science	Pharma, Biotechnology	Any Field
Features	Depend on Industry	Fully Featured	Limited Featured
Weightages	Heavy	Very Heavy	Very Low
Database Usage	MySQL	MySQL, Oracle	Microsoft Server
Task Assignment	Implemented in 2017	Custom Workflow	Manually
Access Level	Complex	More Complex	Easy
Installation	Engineer Require	Engineer Require	Simply Cloud Setup
Invoice can Edit	Yes	No	Yes
Track Activity	Easy	Very Easy	Very Easy
Laboratory Size	Big / Small	Big / Small	Small / Big / Medium
Price	Depend on different hosting	High	Very Low
Training	Hard to access	Required	Easy access

Table 3. 1 Comparison of LIMS Software

3.4. Summary

LIMS software evaluating business process require before investing because there are many LIMS software available on the market and they provide different features with facilities and prices. The expensive end-user clients are needed to use existing LIMS software available in the market since clients are working with a significant amount of data, which increase the hardware cost and it is difficult to purchase the market software for every laboratory. Even most software's are required for the cross-platform program to support enterprise development for increasing initial and ongoing LIMS maintenance expenses. In order to get rid of these limitations, we have

developed web-based LIMS software as a solution. Which provides easy access to all menu and client can design sample test form dynamically with field validation, criteria as per laboratory requirements. In a comparison to the market LIMS software, our LIMS application is very lightweight and it includes all necessary features required for a small laboratory..

4. Planning

Project planning is a division of the whole project working task to accomplish an objective. Planning is the procedure and instruction that create the structure in which all work needs to finish. The project planning is mainly time-based planning to complete tasks and achieve the goal [37] [38]. In this chapter, section 4.1 presents the initial plan, and section 4.2 presents the final plan for the development of this LIMS web-application. As per the discussion with our supervisor, initially, we have planned to research and collect information about LIMS software available in the market and design basic prototypes. Later, we have designed the application which follows the prototypes and start development as per the requirements.

4.1. Initial Plan

Figure 4.1. Shows the initial development plan for the first evolution of LIMS software, which includes schedules, time estimation and efforts given in each iteration. The initial project plan presents using the waterfall methodology framework. With the help of research and requirements, product backlog is created which is mentioned in the Figure 4.1. With the task name and duration, a meeting is fixed after developed product backlog. In a meeting, we have discussed and split the whole project into different modules which are as follows. In this methodology, we follow these steps to analyze, design, develop and test. If it requires to go back into the process, we go back and finish a particular module first. The developer can start development of next phase only after finishing the first module. It means the developer can focus on only one module at a time and finish development of a single module without errors. After research and discussion, we have defined the LIMS software development lifecycle into three main modules, which are as follows:

Software Requirements

- Software Requirements
- Software Design
- Software Development

Based on the requirement, the waterfall model designed as an initial plan using Microsoft management tools.

Following is the initial plan for the project development with the assumption of different periods and tasks.

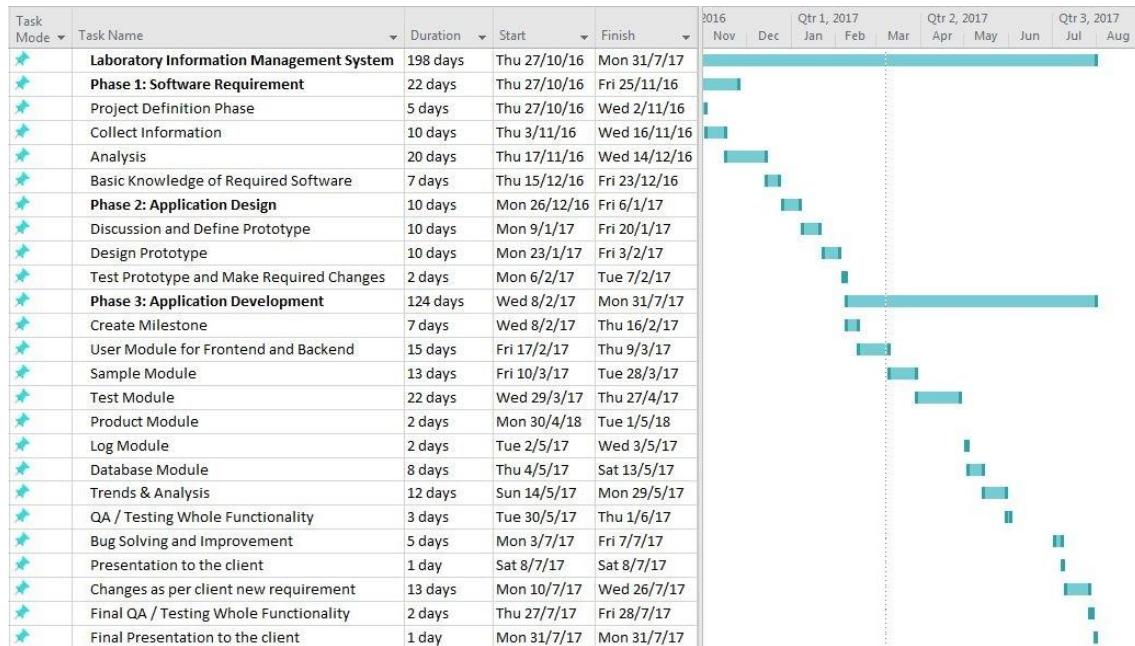| Task Mode	Task Name	Duration	Start	Finish	2016 Nov Dec	Qtr 1, 2017 Jan Feb Mar	Qtr 2, 2017 Apr May Jun	Qtr 3, 2017 Jul Aug
	Laboratory Information Management System	198 days	Thu 27/10/16	Mon 31/7/17				
	Phase 1: Software Requirement	22 days	Thu 27/10/16	Fri 25/11/16				
	Project Definition Phase	5 days	Thu 27/10/16	Wed 2/11/16				
	Collect Information	10 days	Thu 3/11/16	Wed 16/11/16				
	Analysis	20 days	Thu 17/11/16	Wed 14/12/16				
	Basic Knowledge of Required Software	7 days	Thu 15/12/16	Fri 23/12/16				
	Phase 2: Application Design	10 days	Mon 26/12/16	Fri 6/1/17				
	Discussion and Define Prototype	10 days	Mon 9/1/17	Fri 20/1/17				
	Design Prototype	10 days	Mon 23/1/17	Fri 3/2/17				
	Test Prototype and Make Required Changes	2 days	Mon 6/2/17	Tue 7/2/17				
	Phase 3: Application Development	124 days	Wed 8/2/17	Mon 31/7/17				
	Create Milestone	7 days	Wed 8/2/17	Thu 16/2/17				
	User Module for Frontend and Backend	15 days	Fri 17/2/17	Thu 9/3/17				
	Sample Module	13 days	Fri 10/3/17	Tue 28/3/17				
	Test Module	22 days	Wed 29/3/17	Thu 27/4/17				
	Product Module	2 days	Mon 30/4/18	Tue 1/5/18				
	Log Module	2 days	Tue 2/5/17	Wed 3/5/17				
	Database Module	8 days	Thu 4/5/17	Sat 13/5/17				
	Trends & Analysis	12 days	Sun 14/5/17	Mon 29/5/17				
	QA / Testing Whole Functionality	3 days	Tue 30/5/17	Thu 1/6/17				
	Bug Solving and Improvement	5 days	Mon 3/7/17	Fri 7/7/17				
	Presentation to the client	1 day	Sat 8/7/17	Sat 8/7/17				
	Changes as per client new requirement	13 days	Mon 10/7/17	Wed 26/7/17				
	Final QA / Testing Whole Functionality	2 days	Thu 27/7/17	Fri 28/7/17				
	Final Presentation to the client	1 day	Mon 31/7/17	Mon 31/7/17				

Figure 4. 1 Initial Plan for Development of LIMS Web Platform Application

4.2. Final Plan

The project is developed as per the initial plan. Reviewing the process of project development is also made simultaneously at a time of project development. We have already included the review module time into the different modules. After developing a single phase of the project, we have reviewed full functionality and features developed as per the requirements or not. Only after the comparison with the requirement, the next phase has been taken to the development process. At the end of project development, we have set up the test development module; in which we have tested full application and finally solved bugs and errors in bug solving modules. With this process, the whole project developed, and at the end, there was no change in the initial plan and the final plan. After the final test, the project presented to the client. Besides, all requirements fulfilled with the client's requirement and the client had accepted the project at the end of July.

5. Objectives and Methodologies

This chapter explains the goal of this project and how this goal was achieved by research and implementation, understanding of the requirement to develop LIMS software for small laboratories. What technologies we have used and which method we are following to achieve the goal of this project.

Section 5.1 describes the aim of the project and the scope of the work; Section 5.2 describes the objectives of this project, 5.3 presents the functional benefits and requirements, 5.4 presents the technology and software used in this project, in section 5.5 we present the non-functional requirement of the software, and finally in section 5.6 the different Use Cases (UC) are presented.

5.1. Aim and Scope of the work

Currently, a laboratory is working with a large amount of test and results data, which is complicated to manage with papers. It is a time-consuming process, and an existing system is not so efficient to manage a large amount of data. It is also difficult to collect data from different places and generate reports. Design and Implementation of Laboratory Information System come as a better solution with many flexible and convenient features allowing lab administrators and users to maximize efficiency and also reducing time. It gives a solution to keep track of available product, test and results of the particular sample. It will minimize errors and will be an excellent replacement for the existing repetitive manual process. This chapter should clarify which are the goals of the work and how they should achieve.

5.2. Our LIMS Solution

5.2.1. User Interface

A user interface is an essential portion of an application which controls as to how the user will interact with the system. Also, the excellent interface is always leading software to the successful development. Our solution provides a primary and regular user interface which is very easy to understand. Also, with an appropriate title of a page, the user can grab the position that where they are at the same time. In LIMS software, we have different phases with the different name to make it more understandable. The user interface is a little bit different for regular users and admin users. We have present long-term data in a graphical view to quickly analyze, which is running as a new trend.

5.2.2. Selection of .NET framework

In ancient time, LIMS combined the PC's simple and easy user interface; also standardized desktop tools with the power and security of personal computer servers in client-server architecture configuration. The architecture splits data processing between a series of client and database server, which was complicated and costlier. Web-based LIMS introduced as a solution to get of rid from this kind architecture. Previously most of the software developed in different technology. Different web technology is available to develop LIMS software as per different requirements. CTCV have already developed some web application for their use by using .net technology. So, it was the strong requirement to develop this LIMS web-application using the .net technology. However, Microsoft .net technology provides many tools which are very useful in implementation. It is effortless to develop software in a fixed time-period using .net framework technology. The .net framework comes with many interlanguage integrations features such as

inheritance, debugging, standard data types and windows and web-forms. A web application has never been more accessible; cross-platform capability using XML services makes communication with non-windows applications. The installation is simple, and it allows deleting files. The .net framework allows the developer to develop different types of user demand application. With the set of tools, a developer can write code quickly and deliver to the client. Instead of using complicated tools like XML and SOAP, the .net framework wraps up the interface into an easy to use object-oriented structure. Using .net feature classes, tools and other features can speed up the development cycle [39] [40].

5.2.3. Feature Specification

There are many features available in different LIMS software which is not usable for every business. As per our research, many companies are working with specific tests and not with many products; because of this reason, this type of application becomes complicated for a small business. In our web-based LIMS application, we have covered some basic features, which is useful for small business and because of these limited features, the market price of application could be low, which is affordable for a small business. We have plans to visit a small laboratory; their employee is still working with paper and excel sheets. It may be possible to get some idea that how small laboratories are working, after visiting this lab, and we should improve our LIMS software. Following Table 3.2 shows the comparison of our LIMS software activities with the small laboratories activity which are still using spreadsheet and papers for laboratory data management.

Activities	Spreadsheet and Paper Based LIMS	Our Lims Software
Request Tests	Inherent delays, errors in process processing, data multiple time insert and resources are inefficient. Multiple data enter.	Fast turnaround, reduce error and reworks, sharing and integrate data, better customer services, the fast entry with validation.
Receive Samples	Time-consuming entry, incomplete sheets	Get rid form delay reports
Sample Testing	Places for reagents, laborious data entry in registers, resource not available and delays	Single entry to collect data, No error, no delay and no rework.
Analysis	Many delay in check in entries	Generate analyzer report, result report, automatic data captures.
Customer Service	Search data, missing data is time consuming	Immediate feedback online

Table 5. 1 Our LIMS Activities Comparison with Spreadsheet & Paper based LIMS

Regarding the functionality of our LIMS application, several use-case scenarios are defined. These requirements were defined by Prof. João Barata; which will be presented briefly in the next chapter. Our primary goal is to develop a web-based LIMS application for small laboratories with small investment.

Different LIMS software are available in the market which provides different function and features, which is dependent on the size of the laboratory. In all cases, it is a combined time to save and provide accurate data to the customer. Also, the best LIMS software helps to improve

their business and save the time which is wasted on unnecessary paperwork and reports. After analyzing the requirements of a small laboratory, we defined below use cases for our web-based LIMS prototype. The prototype is designed from the start, by the first implementation is illustrated below:

- Different type of users with different access level for security reason.
- Application in Multilanguage: English, Portuguese
- Sample Management: Add, edit and delete sample management.
- Test Management: Design test form as per product test requirements, apply a formula to the particular test, apply multiple test same time.
- Trends and Analyze: Analyze test results and display it in the chart view.
- Complaints: To make direct interaction with clients related test result, reports and improve laboratory test reports which illustrated in Figure 1.1.
- Reports: Generate dynamic reports.
- Defined the project workflow to more comfortable access for the clients to manage laboratory data illustrated in Figure 1.2.

Following is the short depiction of LIMS highlights; executed in our small laboratory LIMS software. Our LIMS software was produced for small laboratories which centered around the Sample, Test results, and Report. This product was created with auto-catch includes in a sample which is extremely useful to gather sample information quick and straightforward, and a client can apply more than one test for a single sample. A client can investigate all sample and test results for the specific time frame as the most recent trend. An objection module helps for coordinating client cooperation, which can help ad lib the laboratory information administration framework.

5.2.3.1. Sampling

Sampling is a main core function of the modern LIMS application. Whether it is pharmaceutical, water treatment, manufacturing laboratories.

- In this application, the client can add Sample details and additionally the user can select a product from the sample page directly.

- In another new feature, the client can apply more than a single test directly from the Add Sample form.

- The product is manageable from the administrator client. An administrator can add or remove products from the backend which influences frontend consequently.

5.2.3.2. Design Test Form

In add new test form, we have placed a somewhat unique component which is not available in the market as of now. It is a dynamic form and utilizing this dynamic form administrator can make another test form, with required fields and the appropriate title of that field. There are; likewise, we have placed dropdown to choose a type of sample so we can characterize that we will plan this dynamic test form for the sample of solid form, liquid form or gas form. This component is accessible for that client who has administrator rights.

5.2.3.3. Add Test

From the add test page, the client can apply a test to a specific sample. In this page search feature is available; through search feature the user can find a test by test name easily. Since there are

numerous samples and test will be added in the future; so, it will be simpler for a representative to discover the sample and test quickly.

5.2.3.4. Auto calculation turnaround time

This software is ideal for performing routine calculations. Our application is combined with the sample tracking and data entry of laboratory data which ideally calculates the turnaround time between a start date and due date. If the calculation is appropriately set up, then it gives an accuracy of a data management system.

5.2.3.5. Automatic Report Generate

One of the most significant time saving and providing accuracy in the result of the tested data is automated report generation feature in LIMS software. In the current generation, reporting means more than a printing report on the paper. In our LIMS software, the user can generate reports for a particular test and able to download that report in PDF format. In the administrator area, a client can filter and evaluates company data for an appropriate year, also able to convert that data into a graphic view and download.

5.2.3.6. Two type of user login

In our LIMS software, we have provided two type of user logins; one is for an employee and another for an administrator user. Employee users can work with samples and test only. Moreover, the administrator can design new test form and set up the result fields criteria. Admin user can analyze the whole LIMS software data and generate a necessary report. Admin user can see the logs of the LIMS software activities. This feature is developed for the quality purpose, which shows activity with the activity name, worked with which activity and by which user.

5.2.3.7. Trends and Analysis

Some latest trend features are developed in our LIMS software application to review the data in a graphical view, which is easier to understand for the users. Because of limited and required features, this application could be affordable for the small organization. There are more features available which are as follows

Trends and Analysis

Quality control is the central aspect of the Laboratories and for a quick overview of the different samples, test results and how it went through in particular time-period. We have developed a simple but useful feature to analyze data, generate result and reports in our LIMS software. This analysis feature allows a user to find data for a specific company. Once the data is filtered by a specific company; users can select a specific sample, which is listed under the particular company. Date ranges give the filtered data for the specific period. Finally, the user can select a field from the result and can find the deviation, minimum, maximum values. The current trend prefers a graphical view to present data because it is straightforward to understand long-term data in a simple format. In the administrator dashboard, an admin user can filter data for a specific company with the specific year. The filter allows displaying only that years which year the data is available in a database. Also, a user can see the data in graphical view like pie and line charts. Besides, a user can convert that graphs in an image view; download it and use it for the different purpose.

5.2.3.8. Complaints

In complaints module, the client can write a few remarks about their organizations' sample result. So, it turns out to manage the resulting process. Moreover, using this feature, the organization can enhance quality or result and get the criticism effortlessly from the client.

5.3. Methodology

The methodology is a set of method and tools to perform a task and describe how the goal should be achieved. The goal of software development must be clear if we are following a traditional cascade approach or more flexible procedure, such as agile programming. If we focus on research, the techniques must have described alongside with the methods for project analysis and clarifying what validation procedure; a ground truth can use.

The objectives state the laboratory requirements to be met by the LIMS. Based on our research and requirements, the objectives of the project are as follows:

- Study and Research about LIMS.
- Design the basic prototypes.
- Select the framework for project development
- Design and Development of LIMS software

We should achieve the goal using waterfall methodology if we want to design and develop a web-based customized LIMS software to manage a small laboratories data like sample, test and generate dynamic reports for a tested sample. Also, filter and analyses the data using a different chart view, which is the latest trend in the market. In software development, waterfall methodology is one of the standard processes to manage software and achieve goals. Waterfall methodology divides a project into small phases. The following Figure 4.1 shows that software development process passed down from one phase to another. Each phase handover the previous stage to another phase with the additional requirements and responsibility and vice versa. This method helps in project management because it follows the current project states with all details and requirements. Once the task finished means that phase of project closed forever [41].
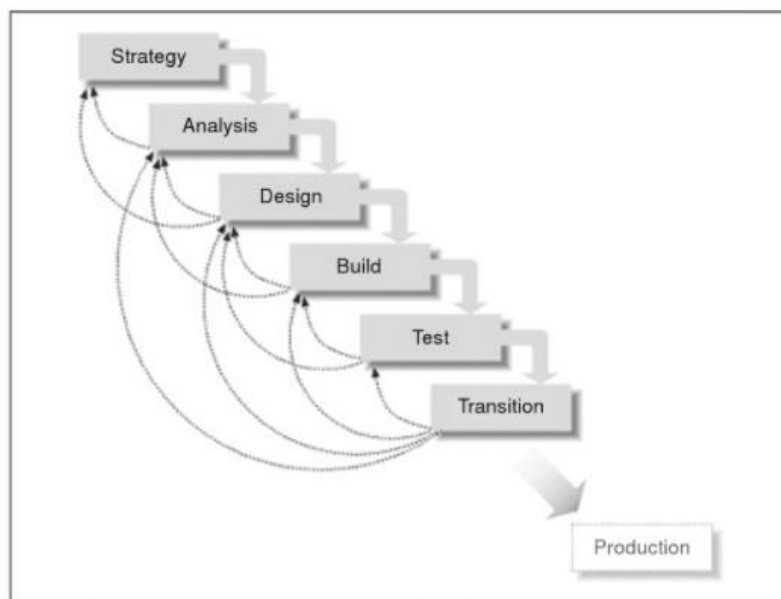

Figure 5. 1 Waterfall Model different phases (From [41])

Study about the LIMS - In this objective of the thesis, we studied about the LIMS software. LIMS stands for Laboratory Information Management System. It helps to improve laboratories operation efficiency by stopping manual task. Moreover, LIMS software automatically records information thereby reducing errors in reports and saving time.

Research about LIMS for Small Laboratories - In this objective, we researched LIMS software available in market for small laboratories. This software is easy to use, and they are providing rapid development option; because all laboratories requirements are changing very quickly. LIMS software allows secure workflow order to the organization; control labs documents; track processing of data records. Moreover, we can generate an error-free report of sample's test and send it to the client electronic way and manage laboratory data secure and better way.

Design basic prototypes - Before we dive into project development, we must start from beginning of the process and test our ideas. The prototype is the initial version of the software and using this prototype; other forms can develop. The prototype is offering how the software will look like and allow a client to change design easy way.

Implementations of LIMS – Development, test, and deployment of a web-based LIMS application for the small organization.

5.4. Software and Technologies

Visual Studio

As per the based-on research and requirement, LIMS software implemented using Visual Studio 2010. Visual Studio enables to build secure and speedy development of our web application. It offers compiler, an advanced editor, easy to use packages and debugger all in one software. The visual studio comes with the variety of services and features, which can help to develop the best application. A different version of Visual Studio is available with upgraded features like Visual Studio 2005, Visual Studio 2008, Visual Studio 2010, Visual Studio 2012, Visual Studio 2013 and the current and latest version is Visual Studio 2016. Mainly this software is written in three parts, which is illustrated in Figure 5.2.

The programming language is a language, which is readable by the humans. Why human-readable; because the computer is not able to understand this language; it only understands binary language. The compiler is doing this translation process during runtime. Also, compiler creates tokenized execution in the Microsoft Intermediate Language, which is a universal language and it converts into the machine language and executes by the computer.
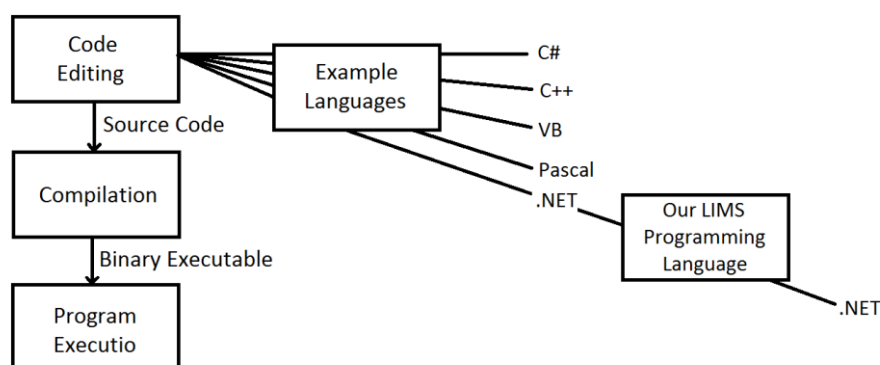

Figure 5. 2 Software written in three parts (From [42])

Visual Studio is a product of Microsoft, and there are several platforms used by the visual studio like Windows Forms, Windows API, Windows Presentation Foundation, Windows Store and Microsoft Silverlight platforms. Visual Studio also supports different programming languages like C, C#.net, VB.net, and C++. Visual Studio can use to develop standalone applications, websites, web services, and web applications. Visual Studio have an inbuilt feature to design web pages for windows applications, web applications, and mobile applications [42].

ASP.NET

Our LIMS web-application developed in ASP.NET language. ASP.NET is an open source framework to develop modern web-apps and web services. LIMS web application implemented using the ASP.NET framework. ASP stands for Active Server Page. ASP.NET pages that created in HTML, which called Web Forms. ASP.NET is a server-side web application framework, and it is developed by Microsoft. This technology mainly designed for development of web application, website and web services. ASP.NET uses the Internet Server Application Programming Interface (ISAPI) to deliver the Hyper Text Transfer Protocol (HTTP) response data to the client side. ASP.NET defined as a language independent. There is a good separation between code and content with ASP.NET. It supports Web Services or Web forms too. Web services provide access to server communication with a remote connection. Fast development can be possible with ASP.NET with robust, scalable with great flexibility with a small piece of code and also we can create web forms. The web application is publishing with Internet Information Services (IIS) server, and it is accessible using the web browser [42].

SQL Server Management Studio

SQL stands for Structured Query Language, which uses to store software data into a table format. SQL Server Management Studio is available in GUI format with server 2008; also, different latest servers are available. A user can configure and manage software data using the Microsoft SQL Server. SQL Server Management Studio provides both GUI even script editor features for data management and a user can manipulate data using this feature. We have used Microsoft SQL Server 2008 for the management of our LIMS web application data.

5.5. Non-Functional Requirement

A non-functional requirement is an essential specification of a system that how it should behave, and it concentrated upon the behavior of a system. The non-functional requirement covers all that requirements, which has not been covered by the functional requirements. Some typical non-functional requirements are performance, security, usability. Following are a list of non-functional requirements of our LIMS web application prototype [43].

Performance

Performance is an amount of task accomplished by the LIMS system. Performance can measure by short response time, low utilization of resources, high availability, and elevated through the output, high bandwidth, and quick data transmission.

Maintainability

It should be easier to maintain a system in the future, and it involves continuous improvement and improve the reliability of a system. It is maximizing product useful for life, increase efficiency, security, and safety of the software.

Reliability

Even after using a long-term, a user must trust on a system. Creating that kind requirement; the system will retain for a long time without change of data or even features. It could be a good idea to include new features that make a system more accessible to monitor system performance.

Usability

Separate different functionality and prioritize them based on natural usage patterns. That functionality is tested by usability, and also used frequently.

Security

Different sensitive information like user credentials, reports that need to protect; and security is most commonly used to protect the data from hostile forces. The system can provide a security alert warning to make a system more secure.

Log

Modern systems usually provide log feature to keep tracks of record performed every task. Log detect the job identifier; task information also includes storage information. Typically, log helps to restore a database to its original state if a system gets frailer or loosed data for some reason. Nowadays, the database management system has special programs, which help a user to operate with the database easy and secure way [44].

Open-source model

Microsoft is providing a full .net server stack in open source, .NET is free, cross-platform with multiple language editor, and library to build a different type of web, mobile, desktop, gaming and IoT applications. An open-source model encourages open collaboration, and it promotes universal access via open-source, free license. Generally, an open-source language is free and provide free source code on the internet. A user can get solutions easily and quickly. Our LIMS software is also developed using the Microsoft .NET framework and, .NET provides a virtual machine where we can run, test and execute our LIMS application [45].

6. Developed Work

This chapter presents an explanation of the implementation and functional requirement of the software development. A software implementation is the process of writing source code for a system. The main objective of this process is to transform the design into program and code modules. The final deliverables of the implementation phase are source code and related documents. The aim of developing a LIMS software is to manage data for a small laboratory with enough set of requirements. As discussed in earlier chapters, the primary objective of this implementation and thesis is to develop a LIMS software with limited features which include basic needs of small laboratories and it could be cost-effective and helpful for a small organization.

A LIMS web application has an implementation of dynamic test design form with the validation of field requirement. Some criteria are defined to compare the value of the report with a sample test. This test form with validation and rules could be the great impression of this LIMS software. Furthermore, it describes different technologies, methods, and patterns used during Laboratory Information Management System development. It also presents the best coding practices used during the implementation process and source code control.

Following is the explanation about the software implementations. However, what features implemented with what programming technology are explained below. Also, the explanation of how we have solved the problem in development with a provided solution is presented below.

6.1. Project Introduction and Discussion

In this duration, we have researched about Industry 4.0, and Industry 4.0 is the latest trend in automation, data exchange and it includes cyber-physical systems, the internet of things (IoT) and cloud computing.

As per the discussion with the company, we wanted to develop that kind of application which can be handled remotely, it implies that an application will be the cloud-based. Also, with the mobile-friendly design, the users can use this application from different devices. After the discussion, we have decided to design this application to be responsive and cloud-based just like other websites running on the internet.

6.1.1. Industrial Visit

Industrial visit was carried out at CTCV[4] Coimbra, Portugal on 27 October 2016 primarily for the second year of Masters in Informatics. The primary motive of this visit was to make us aware of how various activities related to product tests were carried out in the company and provided the best result for the clients. As soon as we reached the company, we were guided by all technologies and how the company works with the sample and make different tests with the different samples. Also, there were lots of testing devices available with enormous size. This industrial visit helped us to define modules and process development.

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[4] CTCV Website - http://www.ctcv.pt/

6.1.2. MES and LIMS

After research and specification about a project, we got two topics; on which we must develop an application, which is MES, abbreviated as Manufacturing Execution System and Laboratory Information Management System (LIMS). The Manufacturing Execution System (MES) is a control system for managing and monitoring Work-in-Process (WIP) on a shop floor and the Manufacturing Information System means production, which can be used anywhere when the requirement arises.

- Latest generation LIMS

New generation laboratories are enhancing work at a lower cost. This situation is becoming more complex. Following are the benefits of LIMS:

Benefits of LIMS:

- Paperless Lab
- Integrated quality
- Reduce scrap & rework
- Reduce IT cost
- Accuracy fewer entry errors
- Less lab administration
- Eliminated application downtime
- Cost-efficient compliance

Start specification and topic chosen

The company has already developed web applications, and there is one developer who is already working with the company software. The software development work is going on with the .net technology and as per the companies' supervisor suggestion, we have started developing this application using .net language, which is new for us. There are various programming languages available for programming advancement; in which we can build up this application, however, after research about improvement, we got software development tool like Visual Studio; which provides many tailor-made modules. These tools can be useful to develop our LIMS application.

Once the specification defined about MES and LIMS, we were suggested by our professor to choose one topic from those two. Moreover, LIMS (Laboratory Information Management System) had been chosen by me, and the other topic MES (Manufacturing Execution System) was chosen by another colleague.

6.2. Requirements

6.2.1. Use Cases

Following use cases characterize to comprehend, the functionality of the LIMS software, and it explains the user has done every activity [46].

6.2.1.1. Staff user use case diagram

The following use case diagram mentioned in Figure 6.1 describes a different activity that can be done by a staff user.
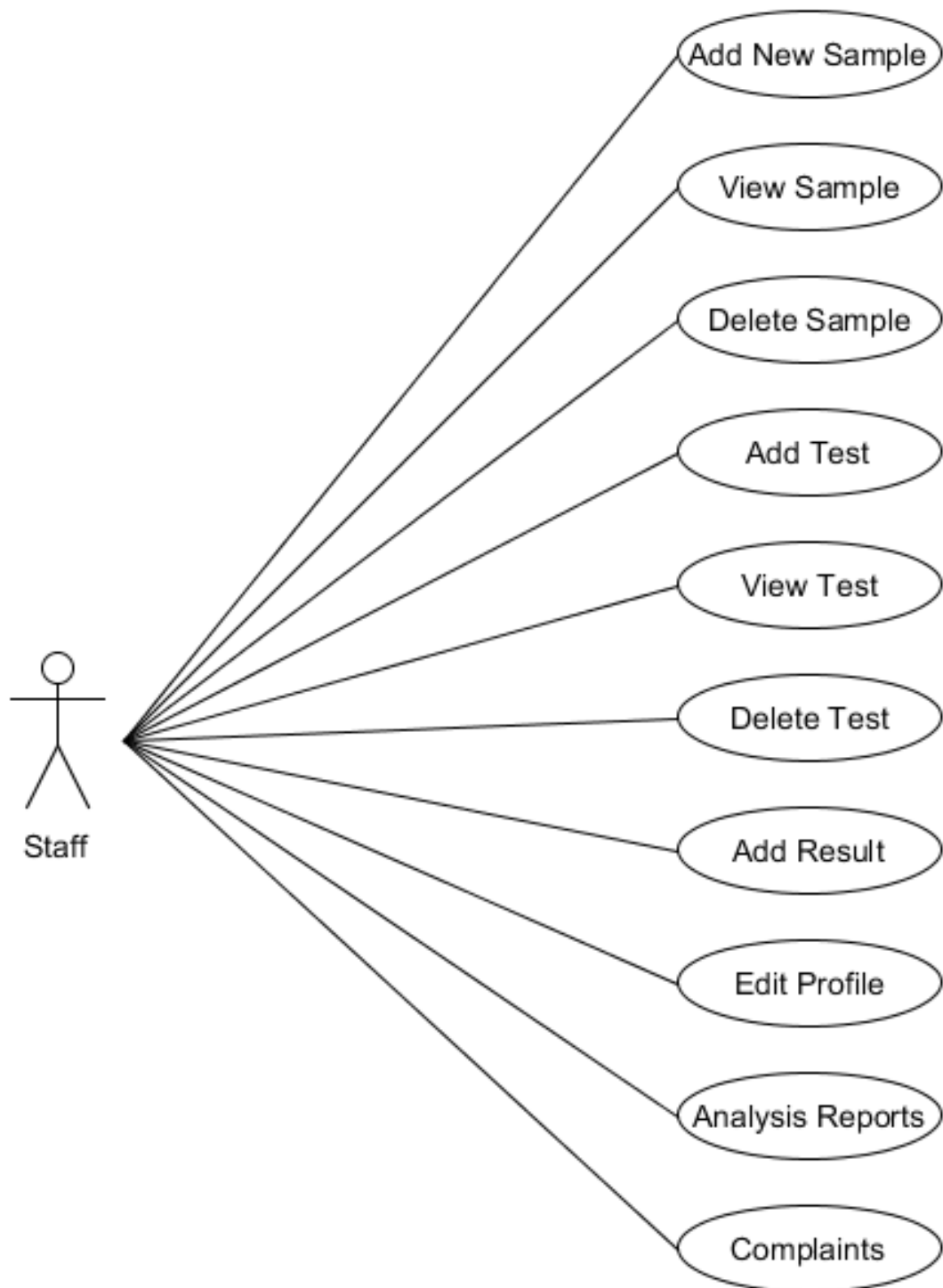
Figure 6. 1 Staff user use case diagram

6.2.1.2. Detailed Staff user use cases

Name	Add New Sample
Short description	User can add new sample
Actors	Employee User
Pre-conditions	The user must have an account
Post-conditions	User must have access to work with add new sample

Main flow of events	1. Add Sample
	   1.1 Open application and login in browser
	   1.2 Select Add Sample from Sample Menu
	   1.3 Insert values and place submit button

Alternative flow of events	1.3.1 Add all require fields 1.3.2 If require fields is empty shows the error 1.3.3 Submit the form

Table 6. 1 Add New Sample

Name	View Sample
Short description	User can view sample details
Actors	Employee User, Admin User
Pre-conditions	The user must have an account
Post-conditions	User must have access to work with view sample

Main flow of events	1. View Sample
	   1.1 Open application and login in browser
	   1.2 Select View Sample from Sample Menu

Table 6. 2 View Sample

Name	Add Test
Short description	User can apply new test to particular sample
Actors	Employee User
Pre-conditions	The user must have an account
Post-conditions	User must have access to work with add sample

Main flow of events	1. Add Test
	   1.1 Open application and login in browser
	   1.2 Select Add Test from Test Menu
	   1.3 Select Sample Name
	   1.4 Select Sample Test and Place Add Test button

Alternative flow of events	1.4.1 Add all require fields 1.4.2 If require fields is empty shows the error 1.4.3 Submit the form

Table 6. 3 Add Test

Name	Add Result
Short description	User can add result of particular test for particular sample
Actors	Employee User
Pre-conditions	The user must have an account
Post-conditions	User must have access to work with delete sample Test must be apply to sample before

Main flow of events	1. Add Result
	    1.1 Open application and login in browser
	    1.2 Select View Test from Test Menu
	    1.3 Select Add Result from list
	    1.4 Fill the result value and submit

Alternative flow of events	1.4.1 Add all require fields 1.4.2 If require fields is empty shows the error 1.4.3 Submit the form

Table 6. 4 Add Result

Name	Delete Sample
Short description	User can delete particular sample, applied test will delete automatic
Actors	Employee User
Pre-conditions	The user must have an account
Post-conditions	User must have access to work with delete sample Sample must be added before

Main flow of events	1. Delete Sample
	    1.1 Open application and login in browser
	    1.2 Select View Sample from Sample Menu
	    1.3 Delete Sample from list using Delete button

Alternative flow of events	1.3.1 After press delete button confirm box will appear 1.3.2 You can select delete/cancel/close button in confirm box

Table 6. 5 Delete Sample

Name	View Test
Short description	User can view list of test applied to the sample
Actors	Employee User
Pre-conditions	The user must have an account
Post-conditions	User must have access to work with view sample

Main flow of events	1. View Test
	    1.1 Open application and login in browser
	    1.2 Select View Test from Test Menu

Table 6. 6 View Test

Name	Delete Test
Short description	User can delete particular test from the list of test
Actors	Employee User
Pre-conditions	The user must have an account
Post-conditions	User must have access to work with delete sample Test must be apply before

Main flow of events	1. Delete Test
	    1.1 Open application and login in browser
	    1.2 Select View Test from Test Menu
	    1.3 Delete Test from list using Delete button

Alternative flow of events	1.3.1 After press delete button confirm box will appear 1.3.2 You can select delete/cancel/close button in confirm box

Table 6. 7 Delete Test

Name	Edit Profile
Short description	User can edit logged in user profile
Actors	Employee User
Pre-conditions	The user must have an account
Post-conditions	User must have access to work with delete sample

Main flow of events	1. Edit Profile
	    1.1 Open application and login in browser
	    1.2 Select profile option from Welcome (username) Menu
	    1.3 Edit profile details and submit form

Alternative flow of events	1.3.1 Add all require fields 1.3.2 If require fields is empty shows the error 1.3.3 Submit the form

Table 6. 8 Edit Staf & User Profile

Name	Analyses Reports
Short description	User can analyze sample reports
Actors	Employee User, Admin user
Pre-conditions	The user must have an account
Post-conditions	User must have access to work with analyze sample report

Main flow of events	1. Analyze Reports
	   1.1 Open application and login in browser
	   1.2 Select analyze option from the Menu
	   1.3 Select different analyze option and submit form

Alternative flow of events	1.3.1 Add all require fields 1.3.2 If require fields is empty shows the error 1.3.3 Submit the form

Table 6. 9 Analyses Report

Name	Complaints
Short description	User can send complaint message
Actors	User
Pre-conditions	The user must have an account
Post-conditions	User must have access to work with complaint area

Main flow of events	1. Contact
	   1.1 Open application and login in browser
	   1.2 Select contact option from the Menu
	   1.3 Fill details with message and submit form

Alternative flow of events	1.3.1 Add all require fields 1.3.2 If require fields is empty shows the error 1.3.3 Submit the form

Table 6. 10 Complaints

6.2.1.3. Admin user use case diagram

The following use case diagram mentioned in Figure 6.2 describes a different activity that can be done by the admin user.
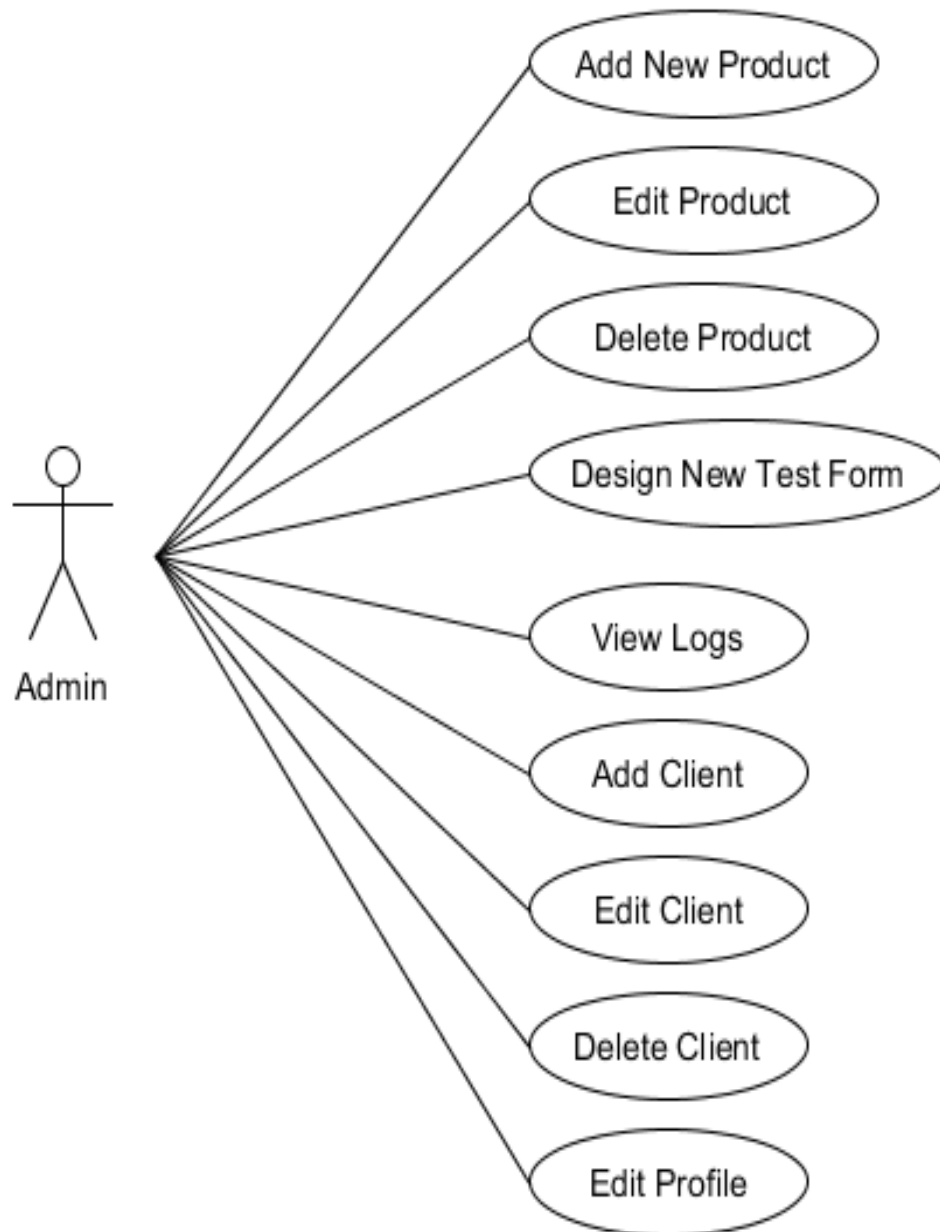

Figure 6. 2 Admin user use case diagram

6.2.1.4. Detailed admin user use cases

Name	Add New Product
Short description	Admin user can add new product
Actors	Admin user
Pre-conditions	The member must have an account
Post-conditions	User must have access to work with add new sample

Main flow of events	1. Add Product
	    1.1 Open application and login in browser
	    1.2 Select Add Product from Product Menu
	    1.3 Insert values and place submit button

Alternative flow of events	1.3.1 Add all require fields 1.3.2 If require fields is empty shows the error 1.3.3 Submit the form

Table 6. 11 Add New Product

Name	Design New Test Form
Short description	Admin user can add new test form
Actors	Admin user
Pre-conditions	The member must have an account
Post-conditions	User must have access to work with add new test form

Main flow of events	1. Add Test Form
	    1.1 Open application and login in browser
	    1.2 Select Add New Test from Test Menu
	    1.3 Create fields as per requirement
	    1.4 Submit form

Table 6. 12 Design New Test Form

Name	View Logs
Short description	Admin user can view user's activities
Actors	Admin user
Pre-conditions	The member must have an account
Post-conditions	User must have access to work with view log

Main flow of events	1. View Log
	    1.1 Open application and login in browser
	    1.2 Select Log from Menu

Table 6. 13 View Logs

Name	Add Company
Short description	Admin user can add a new company(Client)
Actors	Admin user
Pre-conditions	The member must have an account
Post-conditions	User must have access to work with add company(Client)
Main flow of events	1. Add Company 1.1 Open application and login in browser 1.2 Select Add new company from Company Menu 1.3 Fill require fields and submit form
Alternative flow of events	1.3.1 If require fields is empty shows the error 1.3.2 Submit the form

Table 6. 14 Add Company

Name	View Product
Short description	Admin user can view list product
Actors	Admin user
Pre-conditions	The member must have an account
Post-conditions	User must have access to work with view product
Main flow of events	1. View Product 1.1 Open application and login in browser 1.2 Select View Product from Product Menu

Table 6. 15 View Product

Name	Delete Product
Short description	Admin user can view list product
Actors	Admin user
Pre-conditions	The member must have an account
Post-conditions	User must have access to work with delete product Product must be added before
Main flow of events	1. Delete Product 1.1 Open application and login in browser 1.2 Select View Product from Product Menu 1.3 Delete Product from list using Delete button
Alternative flow of events	1.3.1 After press delete button confirm box will appear 1.3.2 You can select delete/cancel/close button in confirm box

Table 6. 16 Delete Product

Name	Edit Product
Short description	Admin user can edit product details
Actors	Admin user
Pre-conditions	The member must have an account
Post-conditions	User must have access to work with edit product

Main flow of events	1. Edit Product
	    1.1 Open application and login in browser
	    1.2 Select View Product from Product Menu
	    1.3 Select Edit Product from list using Edit button
	    1.4 Fill require fields and submit form

Table 6. 17 Edit Product

Name	Delete Test Form
Short description	Admin user can test form
Actors	Admin user
Pre-conditions	The member must have an account
Post-conditions	User must have access to work with delete test form

Main flow of events	1. Delete Test Form
	    1.1 Open application and login in browser
	    1.2 Select View Test from Test Menu
	    1.3 Delete Test from list using Delete button

Alternative flow of events	1.3.1 After press delete button confirm box will appear 1.3.2 You can select delete/cancel/close button in confirm box

Table 6. 18 Delete Test Form

Name	View Company List
Short description	Admin user can view company(Client)
Actors	Admin user
Pre-conditions	The member must have an account
Post-conditions	User must have access to work with view company(Client)

Main flow of events	1. View Company
	    1.1 Open application and login in browser
	    1.2 Select View Company from Company Menu

Table 6. 19 View Company List

Name	Delete Company
Short description	Admin user can delete company(Client)
Actors	Admin user
Pre-conditions	The member must have an account
Post-conditions	User must have access to work with delete company(Client)

Main flow of events	1. Delete Company
	    1.1 Open application and login in browser
	    1.2 Select View Company from Company Menu
	    1.3 Delete Company from list using Delete button

Alternative flow of events	1.3.1 After press delete button confirm box will appear 1.3.2 You can select delete/cancel/close button in confirm box

Table 6. 20 Delete Company

Name	Edit Company
Short description	Admin user can edit company(Client)
Actors	Admin user
Pre-conditions	The member must have an account
Post-conditions	User must have access to work with edit company(Client)

Main flow of events	1. Edit Company
	    1.1 Open application and login in browser
	    1.2 Select View Company from Company Menu
	    1.3 Select Edit option from the list
	    1.4 Edit require fields and submit form

Alternative flow of events	1.4.2 If require fields is empty shows the error 1.4.3 Submit the form

Table 6. 21 Edit Company

6.3. Database ER Diagram

The following diagram illustrates all tables and fields of a database, which is created to store the data of the LIMS application. A client will provide samples for a test, and application requires some space to store this data.

Following Figure 6.3 illustrate, each table is interconnected, and it has a different relationship with each other. How about we view profoundly to comprehend the connection between each table how they are identified with one another and with which element. This database ER diagram is about LIMS. If we talk about a sample, then clients are required, and the database has a table with a named client to store client data. Clients have different products; it can be zero, and more. In the following table, it displays a key(one) symbol in a client table with a different sign; and a product table connected with "+" sign which displays one-to-many relationships between client and product tables. In sentence format, it says, "One client has zero or many products." A product can have more than one sample, so a product table and sample tables are related to one-to-many relationships. At one location we can store one or more samples so location will have a key symbol and sample will have infinite signs, this way we can say that one location has many samples. There are different types of test available for one product; so, a sample will have key sign attached to sample test table with many relationship signs. One sample is having many statuses likewise pending; done, deleted, so sample has one-to-many relationships with sample status table. In this LIMS application, different users have a separate account, and an admin user has rights to see the logs and admin can create one or more test form too. Also, a sample is having one-to-many relationships with log and test form table. A single table must have a primary key, and another table contains a foreign key to make relationships between each other, but a primary key will be only one, and a foreign key can be one and more.
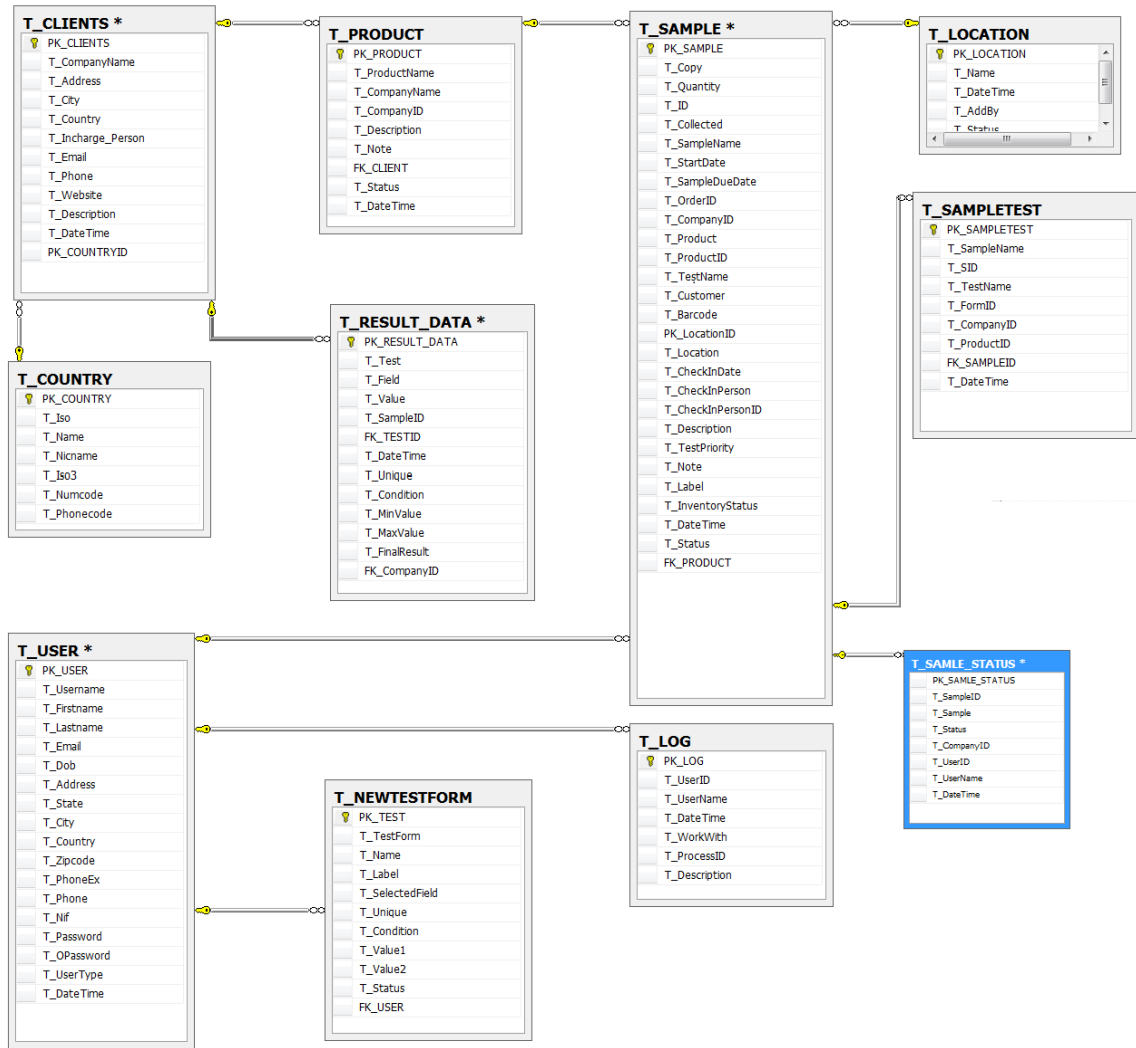
T_CLIENTS *
- 🔑 PK_CLIENTS
- T_CompanyName
- T_Address
- T_City
- T_Country
- T_Incharge_Person
- T_Email
- T_Phone
- T_Website
- T_Description
- T_DateTime
- PK_COUNTRYID

T_PRODUCT
- 🔑 PK_PRODUCT
- T_ProductName
- T_CompanyName
- T_CompanyID
- T_Description
- T_Note
- FK_CLIENT
- T_Status
- T_DateTime

T_SAMPLE *
- 🔑 PK_SAMPLE
- T_Copy
- T_Quantity
- T_ID
- T_Collected
- T_SampleName
- T_StartDate
- T_SampleDueDate
- T_OrderID
- T_CompanyID
- T_Product
- T_ProductID
- T_TestName
- T_Customer
- T_Barcode
- PK_LocationID
- T_Location
- T_CheckInDate
- T_CheckInPerson
- T_CheckInPersonID
- T_Description
- T_TestPriority
- T_Note
- T_Label
- T_InventoryStatus
- T_DateTime
- T_Status
- FK_PRODUCT

T_LOCATION
- 🔑 PK_LOCATION
- T_Name
- T_DateTime
- T_AddBy
- T_Status

T_SAMPLETEST
- 🔑 PK_SAMPLETEST
- T_SampleName
- T_SID
- T_TestName
- T_FormID
- T_CompanyID
- T_ProductID
- FK_SAMPLEID
- T_DateTime

T_RESULT_DATA *
- 🔑 PK_RESULT_DATA
- T_Test
- T_Field
- T_Value
- T_SampleID
- FK_TESTID
- T_DateTime
- T_Unique
- T_Condition
- T_MinValue
- T_MaxValue
- T_FinalResult
- FK_CompanyID

T_COUNTRY
- 🔑 PK_COUNTRY
- T_Iso
- T_Name
- T_Nicname
- T_Iso3
- T_Numcode
- T_Phonecode

T_USER *
- 🔑 PK_USER
- T_Username
- T_Firstname
- T_Lastname
- T_Email
- T_Dob
- T_Address
- T_State
- T_City
- T_Country
- T_Zipcode
- T_PhoneEx
- T_Phone
- T_Nif
- T_Password
- T_OPassword
- T_UserType
- T_DateTime

T_SAMLE_STATUS *
- PK_SAMLE_STATUS
- T_SampleID
- T_Sample
- T_Status
- T_CompanyID
- T_UserID
- T_UserName
- T_DateTime

T_LOG
- 🔑 PK_LOG
- T_UserID
- T_UserName
- T_DateTime
- T_WorkWith
- T_ProcessID
- T_Description

T_NEWTESTFORM
- 🔑 PK_TEST
- T_TestForm
- T_Name
- T_Label
- T_SelectedField
- T_Unique
- T_Condition
- T_Value1
- T_Value2
- T_Status
- FK_USER

Figure 6. 3 ER Diagram of LIMS System

6.4. User interaction prototypes

A prototype is designed instead of solidifying the product necessity before the outline of programming or advancement continues. This way we have designed prototypes intended to understand a fundamental element of LIMS software. Most prototypes were developed based on current basic and known software requirements. Using these prototypes model user can get the real feel of the system [41].

Following are some basic prototypes of LIMS software, which designed as per the research and requirements:

The prototypes are intended and modified more than once, initially, we have discussed and developed some basic prototypes. But after some research, prototypes were modified and designed as follows. It is required to design prototypes as a final user interface for our LIMS application. Because of research for a small laboratory requirement, these prototypes took more time to develop. Finally, our LIMS web-application user interfaces designed and developed as per the following prototypes designs.

6.4.1. Sample Information

Following prototype developed to collect information about the samples as shown in Figure 6.4.

Figure 6. 4 Basic Prototype of Sample Information

6.4.2. Add New Test Form

Following prototype is developed to design a dynamic test form with different fields and different field types like text, number and text area. Also, outlines a dropdown to select a test type, i.e., Gas, Liquid or Solid, with this field user can define the test category, which is illustrated in Figure 6.5.
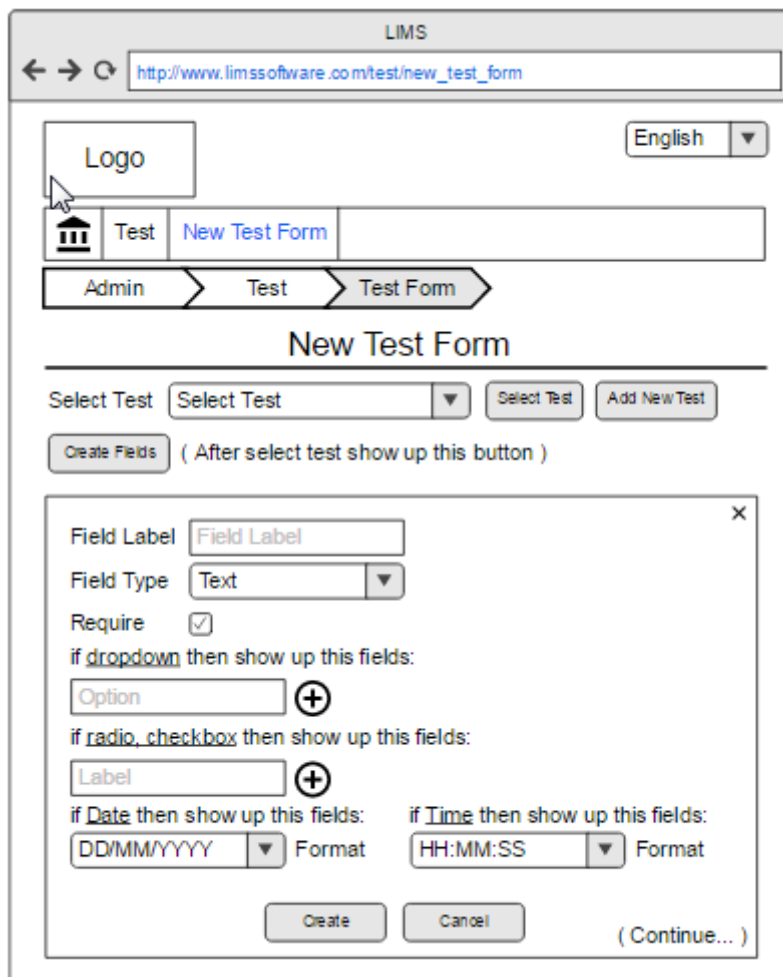

Figure 6. 5 Basic Prototype for Add New Test

6.4.3. Sample Listing

Following prototypes are developed to show the sample and test listing with available fields as shown in Figure 6.6. This prototype helps to display appropriate fields on the sample listing page; because there are more than one fields available in sample and the test forms which are essential and it is required to demonstrate limited fields on listing page, otherwise, a user interface can mess up with the design view.
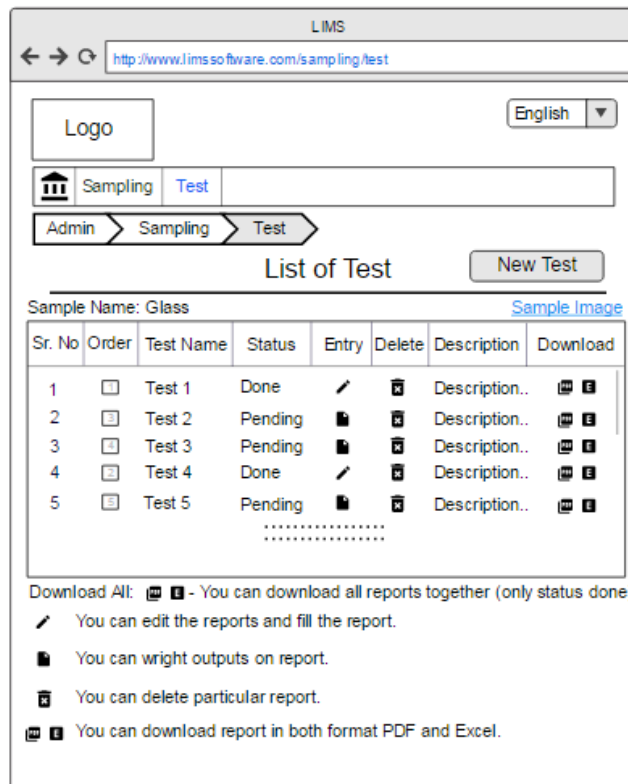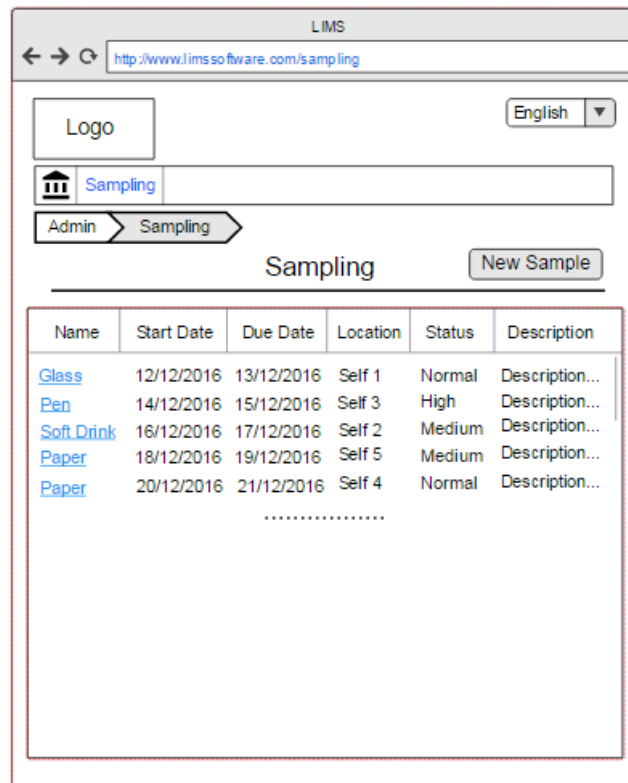
Figure 6. 6 Basic Prototype for Sample & Test Listing.

6.4.4. User Registration Form

Following prototype is developed to cover all the required information about the new user as illustrated in Figure 6.7.

Figure 6. 7 Basic Prototype for User Registration

6.4.5. Sample Report Design

Following prototype is developed to display required information about the test, company, results, time, some description, and some laboratories information which is shown in Figure 6.8. As per the research, some sample report was taken, and we have designed the following report design for our report of the particular test.
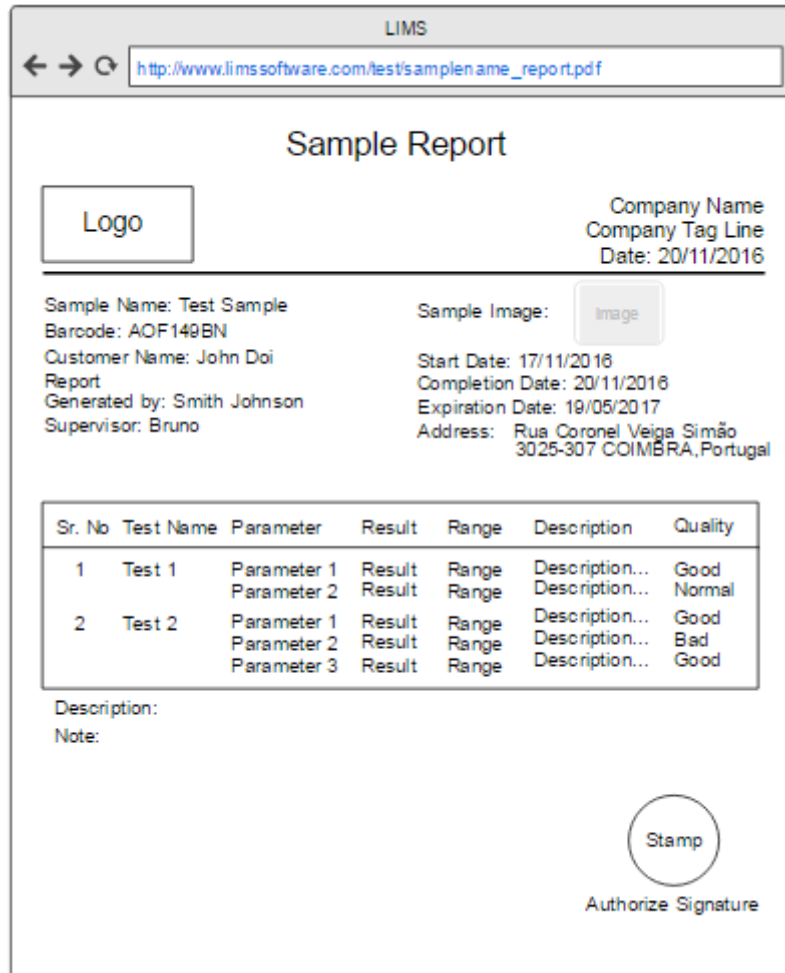

Figure 6. 8 Basic Prototype for Reports

6.5. Implementation

This section illustrates an implementation of a functional requirement of the LIMS software application. This application will implement the concept of sample and test management.

The development work of this thesis will use all the technology discussed in chapter 4, to create a LIMS application.

6.5.1. Project Structure

After setting up an environment of LIMS application in the Microsoft .NET framework, a project directory created default by the .NET framework shown in figure 6.9. It is required to know the project structure before starting the project development process.

Account	05/12/16 4:19 PM	File folder	
App_Data	05/12/16 4:18 PM	File folder	
App_GlobalResources	07/06/17 9:31 PM	File folder	
bin	24/10/17 12:06 AM	File folder	
css	17/05/17 4:57 PM	File folder	
datatables	16/05/17 7:58 PM	File folder	
dist	25/05/17 6:35 PM	File folder	
fonts	05/12/16 4:29 PM	File folder	
images	25/05/17 2:57 PM	File folder	
js	27/06/17 6:55 PM	File folder	
multiple	22/03/17 9:41 PM	File folder	
My Project	05/12/16 4:13 PM	File folder	
new_css	03/05/17 6:53 PM	File folder	
new_fonts	03/05/17 6:53 PM	File folder	
new_js	03/05/17 6:54 PM	File folder	
obj	05/12/16 4:13 PM	File folder	
Scripts	17/02/17 6:08 PM	File folder	
Styles	05/12/16 4:13 PM	File folder	
About.aspx	05/12/16 4:13 PM	ASPX File	
About.aspx.designer.vb	05/12/16 4:13 PM	VB File	
About.aspx.vb	05/12/16 4:13 PM	VB File	
add_formula.aspx	14/09/17 3:54 PM	ASPX File	
add_formula.aspx.designer.vb	14/09/17 3:50 PM	VB File	
add_formula.aspx.vb	14/09/17 6:04 AM	VB File	
add_new_client.aspx	14/09/17 2:21 AM	ASPX File	

Figure 6. 9 Default Project Structure Created by .NET

6.5.2. Web-Forms

A Web-Form is a form that allows the user to enter data on a web page, which is typically sent to the server for processing and the usage of proper forms. We are using forms to send the data to the server and to get a response from the server. Two types of forms (XHTML/HTML) are available in programming language and following elements can be used to design a web-forms [47]

- Input fields:

  - Text: A simple text box which allows the user to insert single line text
  - Checkbox: A checkbox
  - Radio Button: A radio button
  - File: A file selection feature which can help to upload a file on the server.
  - Reset: This button can help us to restore form values as blank.
  - Submit: A submit button can help us to provide a form data with filled data into the form.

- Text-area: It is similar to a textbox, but it allows the user to insert and see multiple rows at the same time.
- Select: A drop-down, which displays a list of item and user, can choose one or multiple.
- JavaScript libraries are available for validation.
- Forms can be combined with different scripting languages to make form dynamic and put validations.

Client-side scripting:

- Usually, JavaScript is used for client-side scripting in web development, because client-side languages are limited and they often can serve the validation of form fields before submitting the form [47].

Server-side scripting:

- The server-side scripting does many tasks to create dynamic websites like form authentication, and a login to retrieve data from the database. Most of the request passes through the web server's universal gateway to execute the program to perform the task [47].

Example of ASP Form:

The Figure 6.10 below illustrates the ASP Login Form Design

```
1 <form role="form">
2   <fieldset>
3     <div class="form-group">
4       <asp:TextBox ID="unm" class="form-control" placeholder="<%$ Resources:Global, Username %>"
5       name="unm" runat="server" autofocus></asp:TextBox>
6     </div>
7     <div class="form-group">
8       <asp:TextBox ID="pwd" class="form-control" textmode="password" placeholder="<%$ Resources:Global,
9       Password %>" name="pwd" runat="server" type="passwrod"></asp:TextBox>
10    </div>
11    <div id="login_error" runat="server" visible="false"><asp:Label ID="Label1" runat="server"
12    Text="<%$ Resources:Global, LoginValidationCorrectPassword %>"></asp:Label></div>
13      <div class="form-group">
14        <div class="row">
15          <span class="text-left col-lg-12 col-md-12 col-sm-12 col-xs-12"><a href="forgot_password.aspx"
16          class="text-right"><asp:Literal ID="Literal1" runat="server" Text="<%$ Resources:Global,
17          ForgotPassword%>" /></a></span>
18        </div>
19      </div>
20      <asp:Button ID="Button1" runat="server" Text="<%$ Resources:Global, Login %>" class="btn btn-lg
21      btn-success btn-block" />
22   </fieldset>
23 </form>
```

Figure 6. 10 ASP.NET Login Form Design

6.5.3. Login Module

This module explains how user authentication works in our LIMS application and it describes the role and operation of different user authentication.

User authentication uses an authentication credential that is created when a user makes registration on the LIMS application. After making login, the user will be redirected to a configured login page, and later on application keep tracks of the user login credentials throughout the site. A user authentication contains inside a cookie or a session. If a user requests a page that requires authenticated access and that user has not previously logged on to the site, the user will automatically redirect to a configured login page. The login page prompts a user for the user credential, typically a username and the password. Then a user credential will pass to the server and validated against a user credential stored in the database. After user credential is authenticated, the user is redirected to the initial requested page. A default attribute of forms values authentication is showing in Figure 6.11.

```
 1 <system.web>
 2   <authentication mode="Forms">
 3     <forms loginUrl="Login.aspx"
 4             protection="All"
 5             timeout="30"
 6             name=".ASPXAUTH"
 7             path="/"
 8             requireSSL="false"
 9             slidingExpiration="true"
10             defaultUrl="default.aspx"
11             cookieless="UseDeviceProfile"
12             enableCrossAppRedirects="false" />
13   </authentication>
14 </system.web>
```

Figure 6. 11 Login form authentication configuration

The HTML design consists of a .NET Framework login control for which the event handler has been specified (See Figure 6.12).

```
 1 <form id="form1" runat="server" role="form">
 2   <fieldset>
 3     <div class="form-group">
 4       <asp:TextBox name="username" runat="server" autofocus></asp:TextBox>
 5     </div>
 6     <div class="form-group">
 7       <asp:TextBox name="password" runat="server" autofocus></asp:TextBox>
 8     </div>
 9     <asp:Button ID="Submit" runat="server" />
10   </fieldset>
11 </form>
```

Figure 6. 12 HTML Design Markup

After the design, the front-end design requires to develop a backend code to check the user credentials, communicate with the database and compare credentials and some security check; it is necessary to import the namespace presented in Figure 6.13.

```
1 Imports System.Data.SqlClient
2 Imports System.IO
3 Imports System.Security.Cryptography
```

Figure 6. 13 Namespaces

The following validate and the stored procedure is used to verify the user credentials. This stored procedure initially checks whether a username and password are correct or not, else it will display an error that user credentials are not valid. If the username and password are correct and a user account has been activated, then username and password will store in the session and system will redirect the user to the defined index page, this process is completed by the code shown in Figure 6.14.

```
1 Protected Sub Button1_Click(ByVal sender As Object, ByVal e As EventArgs) Handles Button1.Click
2         connection.Open()
3         Try
4             Dim userDataAdapter As SqlDataAdapter = New SqlDataAdapter("SELECT * FROM T_LOGIN where
5             U_Username = '" + unm.Text.ToLower() + "'", connection)
6             Dim userDataSet As New DataSet()
7             Dim timestamp As Date = Date.Now.ToString()
8             userDataAdapter.Fill(userDataSet, "T_LOGIN")
9             Dim table As DataTable = userDataSet.Tables("T_LOGIN")
10            Dim username As String = Table.Rows(0)("U_Username").ToString()
11            Dim password As String = table.Rows(0)("U_Password").ToString()
12              If password = encryptPassword(pwd.Text) And type = "1" Then
13                  Dim databaseQuery As String = "UPDATE T_LOGIN SET U_Login_at
14                  ='" + timestamp + "' where U_Email ='" + em + "'"
15                  Dim command As New SqlCommand(databaseQuery, connection)
16                  command.ExecuteNonQuery()
17                  Session("username") = username
18                  Session("password") = password
19                  Response.Redirect("index.aspx")
20              ElseIf password = encryptPassword(pwd.Text) And type = "0" Then
21                  HttpContext.Current.Response.Write("<script>alert('Invalid Login');</script>")
22                  login_error.Visible = True
23              End If
24        Catch ex As Exception
25        End Try
26        connection.Close()
27    End Sub
```

Figure 6. 14 Validate the user credentials

The Figure 6.15 below shows that event handler got a call when Login button clicked. For a single browser login facility, another table has been created to store user credential and email address. If the same user tries to login with the same credential, the system will check into the database, and verifies that the user has already logged into another system or not. If the system found a user has already logged in, then the system will ask a user to log in here in current browser and the user credentials will be updated into the database.

Figure 6. 15 Login Form

Two types of user account login are available in our LIMS application shown in Figure 6.15. When a user tries to login with their credentials, the system will check which user access level assigned to these credentials; if that user has an admin user access then the system will redirect on an admin page; otherwise, the system will redirect that user on index.aspx as explained in Figure 6.14.

The password is encrypted with a given function to make the application more secure, and the security of company data is an essential requirement of any application, which explained in section 5.5. One function is developed to encrypt a password named encryptPassowrd shown in Figure 6.16. A LIMS application is using this function to encrypt a password by passing the string value and make system login procedure more secure. Only the system will know the exact credentials by using this encryptPassowrd function; also, it can establish the other login procedure.

```
1 Protected Function encryptPassword(ByVal password As String) As String
2   Dim data() As Byte = System.Text.Encoding.ASCII.GetBytes(password)
3   data = New System.Security.Cryptography.SHA256Managed().ComputeHash(data)
4   Dim hash As String = System.Text.Encoding.ASCII.GetString(data)
5   Return hash
6 End Function
```

Figure 6. 16 Encryption password

6.6. Work Environment

Our LIMS environment has all the necessary features, which fulfills the requirements of the small laboratories. The list of features is as follows:

- Simple user interfaces with web developed interface.
- Menu with the simple navigation.
- Creation of dynamic test form with criteria.
- Export of the information in various formats like Excel, Word, and PDF.
- Easy search with keywords.
- Sorting of information using the search box.
- Analysis of results using filters.
- Overall data display in a chart view.
- Disable the sample feature.
- Create a system log to track a system process.

6.7. Sample Module

Sample Collection & Sample Scheduling

The sample collection and scheduling are critically important task for a laboratory. With the regards of a sample, collection of features carried out are as follows:

- System checks and validate all require fields.
- Some fields are dynamic, coming from database like company, product, customer, test, and check in person.
- An inserted sample will be shown in the view sample page with the edit and delete feature.

This application validates all fields using the JavaScript scripting language and display an error or success messages. A company product and custom fields are dynamic, so once user will select the company; the system will filter products from the database and displays those products, which is related with the chosen company, and customer name will fill out automated filter from the

database. One more important thing about check-in person field, which by default displays the logged in username. Because of the priority and employee level security, the system allows creating a new user with the different user type. After a sample is inserted successfully; the system will display the Add Test button at the bottom of the sample form to maintain the flow of standard LIMS application as shown below in Figure 6.17.

Figure 6. 17 Add New Sample Form

The Figure 6.17 shows how the sample form looks like and which displays what we have selected, like company named Amiteq and the other field's; product list and customer name are filled out automatically.

Asp.Net have inbuilt feature for the empty field validation which is shown in Figure 6.18. We need to set RequiredFieldValidation tag with the controltovalidate with an error message. Controltovalideate is the id of a particular field, which is required to validate.

```
1 <asp:RequiredFieldValidator ID="RequiredFieldValidator" runat="server" controltovalidate="sName"
2           ErrorMessage="Please enter Sample Name" ForeColor="Red"></asp:RequiredFieldValidator>
```

Figure 6. 18 Blank Field Validation

Now, it is required to store sample data in the database, and we are using SQL database for the data management. In asp.net, it is required to import libraries if we want to use some external features. SqlClient is imported to use the third-party database in asp.net. After importing this library; using SQL Connection; we have made a connection with the database. Moreover, it is required to open a connection using the connection.open() function before we do any operations with the database, and after making some operation with the database, it is required to close the connection using the connection.close() function as shown in Figure 5.19.

```
1 Imports System.Data.SqlClient
2
3 Dim connectionString As String = ConfigurationManager.ConnectionStrings
4                         ("LIMS_DATABASE_CONNECTION").ConnectionString
5 Dim connection As SqlConnection = New SqlConnection(connectionString)
6
7 connection.Open()
8     //DO YOUR STUFF HERE
9 connection.Close()
```

Figure 6. 19 Connection to SQL Database

After making a connection with the database using insert query with parameters, the application will insert sample data into the database. The Figure 6.20 below shows how to write SQL query and how to set parameters with value to enter data into the database.

```
1  Dim databaseQuery As String = "INSERT INTO T_SAMPLE (T_Copy,T_Quantity,T_ID,T_Collected,
2  T_SampleName,T_StartDate,T_SampleDueDate,T_OrderID,T_CompanyID,T_Product,T_ProductID,
3  T_Customer,T_Barcode,PK_LocationID,T_Location,T_CheckInDate,T_CheckInPerson,T_CheckInPersonID,
4  T_Description,T_TestPriority,T_Note,T_Label,T_InventoryStatus,T_DateTime,T_Status,FK_PRODUCT)
5  VALUES (@T_Copy, @T_Quantity, @T_ID, @T_Collected, @T_SampleName, @T_StartDate, @T_SampleDueDate,
6  @T_OrderID, @T_CompanyID, @T_Product, @T_ProductID, @T_Customer, @T_Barcode, @PK_LocationID,
7  @T_Location, @T_CheckInDate, @T_CheckInPerson, @T_CheckInPersonID, @T_Description, @T_TestPriority,
8  @T_Note, @T_Label, @T_InventoryStatus,@T_DateTime, @T_Status, @FK_PRODUCT)"
9  Dim command As New SqlCommand(databaseQuery, connection)
10 command.Parameters.AddWithValue("@T_Copy", Request.Form("cpy").ToString)
11 command.Parameters.AddWithValue("@T_Quantity", Request.Form("qty").ToString)
12 command.Parameters.AddWithValue("@T_ID", ids.Text)
13 command.Parameters.AddWithValue("@T_Collected", Request.Form("collect").ToString)
14 command.Parameters.AddWithValue("@T_SampleName", samplenm.Text)
15 command.Parameters.AddWithValue("@T_StartDate", Request.Form("sdate").ToString)
16 command.Parameters.AddWithValue("@T_SampleDueDate", Request.Form("ddate").ToString)
17 command.Parameters.AddWithValue("@T_OrderID", ord.SelectedItem.Text)
18 command.Parameters.AddWithValue("@T_CompanyID", ord.Text)
19 command.Parameters.AddWithValue("@T_Product", Product.SelectedItem.ToString())
20 command.Parameters.AddWithValue("@T_ProductID", Product.SelectedValue)
21 command.Parameters.AddWithValue("@T_Customer", companyperson.Text)
22 command.Parameters.AddWithValue("@T_Barcode", bcode.Text)
23 command.Parameters.AddWithValue("@PK_LocationID", locat.SelectedItem.Value)
24 command.Parameters.AddWithValue("@T_Location", locat.SelectedItem.Text) 'location.SelectedValue.ToString()
25 command.Parameters.AddWithValue("@T_CheckInDate", Request.Form("cid").ToString)
26 command.Parameters.AddWithValue("@T_CheckInPerson", chkperson.SelectedItem.Text)
27 command.Parameters.AddWithValue("@T_CheckInPersonID", chkperson.SelectedItem.Value)
28 command.Parameters.AddWithValue("@T_Description", descr.Text)
29 command.Parameters.AddWithValue("@T_TestPriority", testp.Text)
30 command.Parameters.AddWithValue("@T_Note", note.Text)
31 command.Parameters.AddWithValue("@T_Label", lbl.Text)
32 command.Parameters.AddWithValue("@T_InventoryStatus", inventory_status.Text)
33 command.Parameters.AddWithValue("@T_DateTime", DateAndTime.Now)
34 command.Parameters.AddWithValue("@T_Status", 0)
35 command.Parameters.AddWithValue("@FK_PRODUCT", tb.Rows(0)("PK_PRODUCT").ToString())
36 HttpContext.Current.Response.Write("<script>alert('Data inserted successfully....');</script>")
37 command.ExecuteNonQuery()
38 Response.Redirect("new_sample.aspx?add=yes#scroll_down")
```

Figure 6. 20 Add Sample Data in Database

A user can check the status of a sample on the sample view page after inserting it successfully. The sample listing page will display the sample test which is an ongoing sample, or which is already completed. A user is also able to filter the samples with status like ongoing, disabled or completed. This web application provides a natural search feature, which helps the user to filter data by the keywords and there is also download feature which is available to download the list of tests. Therefore, a user can filter data by keywords, sorting by just one click on the title of a table and also, the user can download whole or filtered data in different formats like CSV, Excel, PDF even print that filtered data too.

The system will display an option to apply the test to an added sample, once a sample inserted into the database. The Figure 6.21 illustrates the list of all combined samples. Here, we can see that user can find any sample data with the keywords and also, a drop-down option is available to filter data with different status of a sample like Completed, Ongoing or Disabled, CSV, or Excel. This button allows a user to download visible data in various formats. Moreover, data is in tabular format with pagination, so it makes information simplified to view.

Samples

On Going samples are listed below, you can filter it with Completed Or Disabled Status.

Select Status ▾

Copy	CSV	Excel	PDF	Print

Search:

Sample ID ↓↑	Sample Name ↓↑	Company Name ↓↑	Start Date ↓↑	Due Date ↓↑	Location ↓↑	Priority ↓↑	Status ↓↑	Description ↓↑
1	Agua	Web Tech LDA	2017-06-08	2017-07-15	Fridge	High	On Going	Test Description ☑
2017001	Soft Water	aemiteq	2017-06-20	2017-06-26	Fridge	Normal	On Going	Soft water ☑
2017002	Soft Water	aemiteq	2017-06-30	2017-07-31	Self 1	Normal	On Going	☑
20170003	Soft Water	CTCV	2017-06-30	2017-07-	Self 1	Medium	On Going	☑
Sample ID	**Sample Name**	**Company Name**	**Start Date**	**Due Date**	**Location**	**Priority**	**Status**	**Description**

Showing 1 to 10 of 19 entries

Previous	1	2	Next

Figure 6. 21 View Sample List

Using the external JavaScript and CSS libraries the system can display laboratory data in a table format with features like search, download data in a different format. Also, data will display with pagination in a tabular format as shown in Figure 6.22.

```
1 https://code.jquery.com/jquery-1.12.4.js
2 https://cdn.datatables.net/1.10.16/js/jquery.dataTables.min.js
3 https://cdn.datatables.net/1.10.16/css/jquery.dataTables.min.css
```

Figure 6. 22 JavaScript, CSS Library

After adding this library, it is required to design in a tabular format, which is necessary to display data in a tabular format with search, filter export features as shown in Figure 6.23. It is required to set a unique id to handle this feature dynamically. In the following figure, we have to set an id with the name "sample," which is a unique ID (UID) and that external library will provide this feature using this unique id only.

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```
 1 <table id="sample" class="display" style="width:100%">
 2   <thead>
 3     <tr>
 4       <th>Name</th>
 5       <th>Position</th>
 6       <th>Office</th>
 7       <th>Age</th>
 8       <th>Start date</th>
 9       <th>Salary</th>
10     </tr>
11   </thead>
12   <tbody>
13   <tr>
14     <td>Tiger Nixon</td>
15     <td>System Architect</td>
16     <td>Edinburgh</td>
17     <td>61</td>
18     <td>2011/04/25</td>
19     <td>$320,800</td>
20   </tr>
21   </tbody>
22   <tfoot>
23   <tr>
24     <th>Name</th>
25     <th>Position</th>
26     <th>Office</th>
27     <th>Age</th>
28     <th>Start date</th>
29     <th>Salary</th>
30     </tr>
31   </tfoot>
32 </table>
```

Figure 6. 23 Pagination Table Format

Once a table is designed in HTML, it is required to add one jQuery snippet to make all features work. The Figure 6.24 illustrates jQuery is required with the same ID, which we have set in HTML table tag. We can set any name as we prefer but it is a must to set the same name in this jQuery function and in HTML table tag to make this feature working.

```
1 $(document).ready(function() {
2     $('#sample').DataTable( {
3         "pagingType": "full_numbers"
4     } );
5 } );
```

Figure 6. 24 Pagination jQuery

Note that we have used this same library and feature like search, filter, pagination and export files in different format. It is just required to call another jQuery function for different tables because the ID is unique for all tables in whole LIMS application.

Sample Disable:

Sample disable feature is available only for admin users. This feature is just changing one parameter true or false in a database. Initially, at the time of inserting the sample data, it will be true by default. When an admin user taps this disable button, the application will change that true value to false in a database and further sample process will be done by the status of this sample. If the system loads a sample page in the front office after making this change, a user will not be able to see this sample anymore. Even the test and results will affect this disabled sample. One disable (eye) symbol is available in the list of samples to disable a sample as shown in Figure 6.25.

Figure 6. 25 Sample disable

6.8. Test Module

One of the significant risks of any LIMS system is related to the high-level mistaken data entries rate. On the other hand, it is vital that we can provide an analyst that this sample is most urgent to prioritize and assign a status to each result. In test module, the user can select a particular sample, then the system will display only that test which does not apply to the chosen sample. A user is also able to apply more than one test to selected sample by selecting more test from the dropdown of test list shown in following Figure 6.26.

Figure 6. 26 Apply Test

Test list will display only that test which is not applied to any sample. An application will store a selected test in one hidden field separated by a comma, and the field ID is "add_new_test_hidden_field" to add multiple tests at the same time. After selection of test, when the user will submit the form, the application will get that test name stored in the hidden field with separated by a comma, split all test, and using for each loop insert all test into the database with given snippet of code in Figure 6.27.

```vb
 1 Dim test_array As String = Request.Form("add_new_test_hidden_field")
 2 Dim tests As String() = test_array.Split(New Char() {","c})
 3 Dim test As String
 4   Dim selectedItem As String = ""
 5   For Each test In tests
 6       Dim a As String = "SELECT * FROM T_NEWTESTFORM where T_Name ='" + test.ToString + "'"
 7       Dim userData As SqlDataAdapter = New SqlDataAdapter(a, connection)
 8       Dim userSet As New DataSet()
 9       userData.Fill(userSet, "T_NEWTESTFORM")
10       tb = userSet.Tables("T_NEWTESTFORM")
11
12       Dim tst As String = DropDownList2.SelectedItem.Text
13       Dim outp() As String = tst.Split("-")
14
15       Dim databaseQuery As String = "INSERT INTO T_SAMPLETEST (T_SampleName,T_SID...)
16       VALUES (@T_SampleName,@T_SID...)"
17       Dim commands As New SqlCommand(databaseQuery, connection)
18       commands.Parameters.AddWithValue("@T_SampleName", outp(0).ToString)
19       commands.Parameters.AddWithValue("@T_SID", tb1.Rows(0)("T_ID"))
20       ...............................................
21       commands.Parameters.AddWithValue("@T_DateTime", DateAndTime.Now)
22       commands.ExecuteNonQuery()
23   Next
24 End Sub
```

Figure 6. 27 Apply Multiple Test

In above Figure 6.27, LIMS application will get the test names which is stored in a hidden field using Request.Form(). After getting tests, name application will split the test names using "split" function and run a "for-loop" and insert data into the database.

Once a single or multiple test is added into the database, the system will redirect on test view page. On this page, a user can see all test in same table format with search, pagination and exports features as explained in sample module and the table of test list view will look like Figure 6.28. We can see this table is showing multiple tests with different actions like "Add Result," with delete (✖) and view results (🔲) buttons. A user can insert more than one result for a single test by using the Add Result button. With delete, button user can delete the applied test for a particular sample. Moreover, the view result will display all results, which is inserted for a single test.

Figure 6. 28 View Test List

The Figure 6.29 illustrate the sample of add result form. This form field and criteria of every field will not be the same; it will change as per the test requirement. This form can design dynamically by an admin user.

Figure 6. 29 Add Test Result

When a user taps add result button: an application will validate all fields using jQuery function. Another function created for validating a blank field and also criteria like numeric, numbers between, number less than and a number higher than inserted value, that function called "newtestform_validation()" which is as shown in following Figure 6.30.

```
1 var count = document.getElementById("count").value;
2 for (i = 1; i <= counter1; i++) {
3   if ($("#input" + i).val() == "") {
4     $("#input" + i).next("span").remove();
5     if ($("#input" + i).attr('name') != "Formula") {
6         $("#input" + i).after(
7           "<span class='req input" + i + "'>Please enter require field</span>
8         ");
9         document.getElementById("b_register").disabled = true;
10    }
11  }
12 }
```

Figure 6. 30 Test Blank Field Validation

This jQuery function can get a sum of fields from one hidden field, where the application stored the total number of fields when the dynamic form is loading from the database. The system checks all inputs by its unique ID, and if any field finds without values, it will generate error span tag with error text and make it visible.

If that function will not find an empty field in the loop; it will check for other criteria in that same "for-loop" with the result of those fields. There are different types of criteria for input type numeric such as "<=" (less than or equals) ">=," (greater than or equals) or "Between." We have set a short form to compare criteria, following is one example of less than or equal value criteria example. This function will check if the value is "le" it means less than or equals and it will compare the value inserted in the textbox with the criteria value set by the admin. If it found ok, and condition will get true (line no 4); this function will do nothing. If it is found false, then this function will check else part (line no 7) and add error span after the textbox with like "Please enter a value less than or equal" and after this error text dynamic value will append which is the criteria value set by an admin.

```
1 if (result[0] == "le") {
2    var value = parseFloat("" + $("#input" + i).val());
3    var match_value = parseFloat("" + result[1]);
4    if (value <= match_value) {
5      document.getElementById("b_register").disabled = false;
6      formula_counter = 1;
7    } else {
8      document.getElementById("b_register").disabled = true; $("#input" + i).next("span").remove();
9      $("#input" + i).after("<span class='req input" + i + "' style='color:red; '>
10       Please enter value less then or equal " + result[1] + "</span>");
11     formula_counter = 0;
12   }
13 }
```
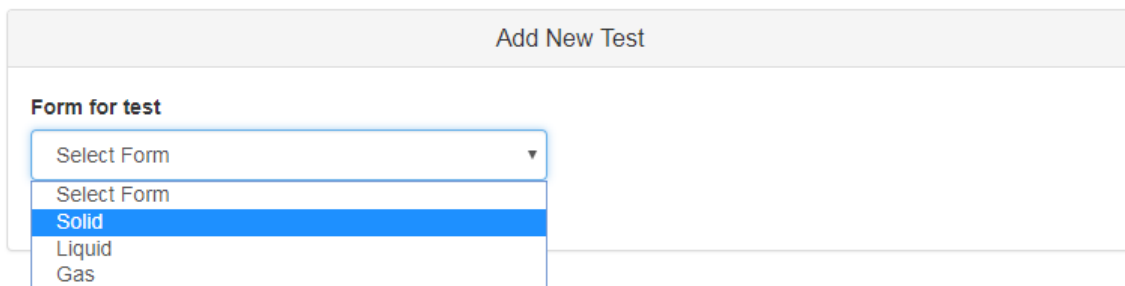
Figure 6. 31 Criteria Validation

Line number 5 will enable 'Add result' button and allows a user to modify a value of number field and add result again. If the criteria do not match with the criteria value, it will show an error, but next time the system will allow insert values and complete the add result process. A user can add multiple results for a single test.
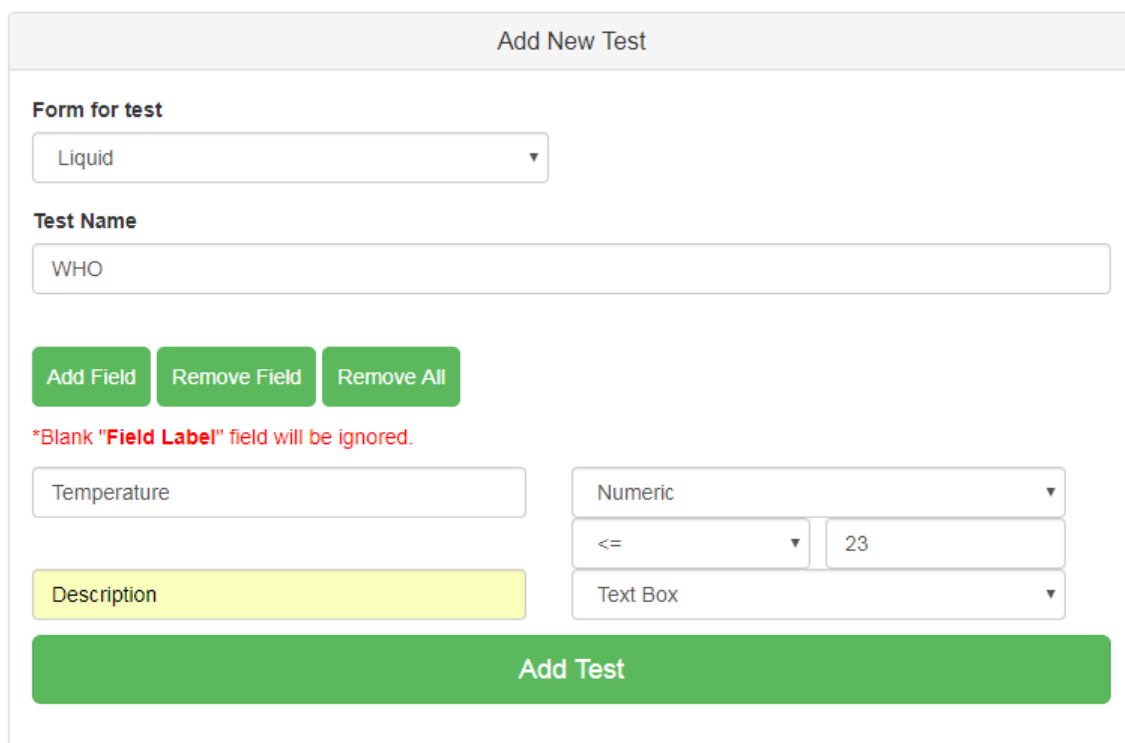
Admin Design Test Form:

Only an admin user will have access to design a new test form, and initially, a user needs to define the type of test form, which is "Solid," "Liquid" or "Gas" as shown in Figure 6.32.

Figure 6. 32 Selection Test Type

Once the test type is selected; an application will display the form where an admin user can create new fields with criteria as shown in Figure 6.33. Following is an example of designed new test form. One field design with name Temperature, with the numeric criteria, and it needs to be less than or equals 23. Moreover, another field named Description which is the textbox.

Figure 6. 33 Design New Test Form

Above designed test form shown in Figure 6.33, will look like Figure 6.34. After a design test form, the blank fields validation and the criteria of that field will work as explained in the added test section.

Figure 6. 34 Designed Test Form

Also, a user can see the criteria written dynamically at textbox placeholder. Other field named Enter Method, date, and Enter unit was set as per the client's requirement. Because Client Company keeps track of result by putting the date; and they have their own method. Also, it is required to enter the unit for them. Those fields are optional; a user does not need to enter any value in it. A system will consider as a blank field if there is no value found and keep those fields also blank in a database.

Figure 6.35, illustrates validation of field at a time of designing new test form. An application will check whether it is a numeric value, textbox, text area or yes/no field. If it appears numeric value; the application will check another dropdown for condition; if another dropdown value is "between,"; the system will display two text boxes. So, a user can define min and max value. If the condition will "<=" or ">="; the system will display a single text box to define criteria value and design a form same like front office 'add test result' form. Moreover, an application will add parameters which follows criteria as an admin user has defined at a time of design test form, and it is required to enter unit also. Those fields designed as per the client requirements. A user can put those field without entering any value because those fields are not required, and it will keep empty in a database.

```
 1 If Request.Form("selectcondition" + b) = "bt" Then
 2 value2 = value2 + 1
 3   Dim val2 As String = b.ToString + value2.ToString
 4   'filds.InnerHtml = filds.InnerHtml + Request.Form("tb" + b).ToString + "_"
 5   + Request.Form("tbl" + b).ToString + "_" + Request.Form("condition" + b).ToString
 6   + "_" + Request.Form("condition" + maxval.ToString).ToString + "-"
 7   Dim query1 As String = "INSERT INTO T_NEWTESTFORM (T_TestForm,T_Name,T_Label,
 8   T_SelectedField,T_Unique,T_Condition,T_Value1,T_Value2,T_Status,FK_USER) VALUES (
 9   @T_TestForm,@T_Name,@T_Label,@T_SelectedField,@T_Unique,@T_Condition,@T_Value1,@T_Value2,
10   @T_Status,@FK_USER)"
11   Dim command1 As New SqlCommand(query1, connection)
12   command1.Parameters.AddWithValue("@T_TestForm", Form.SelectedValue.ToString())
13   command1.Parameters.AddWithValue("@T_Name", tname.Text)
14   command1.Parameters.AddWithValue("@T_Label", Request.Form("tb" + b).ToString)
15   command1.Parameters.AddWithValue("@T_SelectedField", Request.Form("tbl" + b).ToString)
16   command1.Parameters.AddWithValue("@T_Unique", unique)
17   command1.Parameters.AddWithValue("@T_Condition", Request.Form("selectcondition" + b).ToString)
18   command1.Parameters.AddWithValue("@T_Value1", Request.Form("condition" + b).ToString)
19   command1.Parameters.AddWithValue("@T_Value2", Request.Form("condition" + val2).ToString)
20   command1.Parameters.AddWithValue("@T_Status", 0)
21   command1.Parameters.AddWithValue("@FK_USER", Session("auid"))
22   command1.ExecuteNonQuery()
23 End If
```

Figure 6. 35 New Test Validation

As the next step of add design new test form application; if system does not find any numeric value; then the application will run an else part and insert that form data as the admin user has set criteria in design the new test form shown in Figure 6.36.

```
 1 If Request.Form("selectcondition" + b) = "bt" Then
 2 value2 = value2 + 1
 3   Dim query5 As String = "INSERT INTO T_NEWTESTFORM (T_TestForm,T_Name,T_Label,
 4   T_SelectedField,T_Unique,T_Condition,T_Value1,T_Value2,T_Status,FK_USER)
 5   VALUES (@T_TestForm,@T_Name,@T_Label,@T_SelectedField,@T_Unique,@T_Condition,
 6   @T_Value1,@T_Value2,@T_Status,@FK_USER)"
 7   Dim command5 As New SqlCommand(query5, connection)
 8   command5.Parameters.AddWithValue("@T_TestForm", Form.SelectedValue.ToString())
 9   command5.Parameters.AddWithValue("@T_Name", tname.Text)
10   command5.Parameters.AddWithValue("@T_Label", Request.Form("tb" + b).ToString)
11   command5.Parameters.AddWithValue("@T_SelectedField", Request.Form("tbl" + b).ToString)
12   command5.Parameters.AddWithValue("@T_Unique", unique)
13   command5.Parameters.AddWithValue("@T_Condition", "no")
14   command5.Parameters.AddWithValue("@T_Value1", "no")
15   command5.Parameters.AddWithValue("@T_Value2", "no")
16   command5.Parameters.AddWithValue("@T_Status", 0)
17   command5.Parameters.AddWithValue("@FK_USER", Session("auid"))
18   command5.ExecuteNonQuery()
19 End If
```

Figure 6. 36 Insert Test Fields in Database

Once a test form is designed and inserted in the database, an application will redirect to the test view page. In a test list page, the test will display same as other tables; with the same feature of search, pagination and export formats. From an action field, a user can delete the test form, disable the test form and Add a Formula for that test form. Using this feature admin user can add a formula for fields created in newly designed test form. If the method is already added in a test, the system will only allow to Remove that Formula instead of Add Formula.

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Test

Figure 6. 37 View Test Form List

When a user tries to add a formula, the application will check if the test has applied to any sample or not. If this test is already applied for any sample, an application will show an alert like "You are not allowed to add the formula for this test, as it has been applied to other samples" as shown in Figure 6.38.
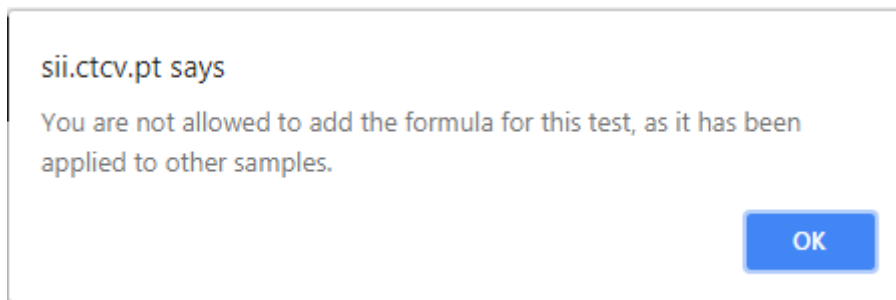
Figure 6. 38 Can't add Formula

Add formula form will look like Figure 6.38, and it will list out the numeric fields from the designed test form. Also, we can see in Figure 6.39; an application will allow a user to "add," "Subtract," "Multiply," "Division," "Less than," "Less than equals," "Greater than," "Greater than equals" with two field values.

Figure 6. 39 Add Formula

Once the field is added in front-end, the backend will work like following: Initially, the system will get a field index value, and using a for-loop insert all fields in a database. This formula is related with single test form in which it is created, and it will display at the end of the Add test result form with the criteria and validations. This adding formula code is illustrated in Figure 6.40.

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```
 1 Dim fields As Integer = field_index.Value
 2   Dim value1 As String = ""
 3   Dim value2 As String = ""
 4
 5   Dim output1 As String
 6   Dim output2 As String
 7   For i As Integer = 1 To fields
 8     If i = 1 Then
 9       value1 = value1 + field_1.SelectedItem.Value
10       value2 = value2 + field_1.SelectedItem.Text
11     Else
12       Dim array As String = Request.Form("field_" + i.ToString())
13       Dim flds As String() = array.Split(New Char() {"_"c})
14       output1 = flds(0).ToString
15       If flds.Length = 1 Then
16         output2 = flds(0).ToString
17         output1 = flds(0).ToString
18       Else
19         output2 = flds(1).ToString
20       End If
21       value1 = value1 + " " + Request.Form("condition_" + i.ToString()) + " " + output2
22       value2 = value2 + " " + Request.Form("condition_" + i.ToString()) + " " + output1
23
24   End If
25 Next
```

Figure 6. 40 Add Formula in Database

6.9. Log Module

A system log contains records of events done by the application. A user can track the system events like what task has been done by which user at what time using this log feature. Following Figure 6.41 illustrates the log of application; in this log table, the system will store Username, Date/Time, Work with and Description. In Figure 6.41, Sr. No one displays that an admin user had worked with Add New Product and the Product ID is 1, and only admin user has access to delete those logs.

Figure 6. 41 Logs

The system will insert log data into the database using the insert query shown in Figure 6.42. The system will insert logs data in a database with the short explanation about which user has done what process with the application.

```
1  Dim dbQuery As String = "INSERT INTO T_LOG (T_UserID,T_UserName,T_DateTime,
2    T_WorkWith,T_ProcessID,T_Description) VALUES (@T_UserID,@T_UserName,
3    @T_DateTime,@T_WorkWith,@T_ProcessID,@T_Description)"
4    Dim cmd As New SqlCommand(dbQuery, connection)
5    cmd.Parameters.AddWithValue("@T_UserID", Session("auid").ToString)
6    cmd.Parameters.AddWithValue("@T_UserName", Session("ausername"))
7    cmd.Parameters.AddWithValue("@T_DateTime", DateAndTime.Now)
8    cmd.Parameters.AddWithValue("@T_WorkWith", "Add New Product".ToString)
9    cmd.Parameters.AddWithValue("@T_ProcessID", uid.ToString)
10   cmd.Parameters.AddWithValue("@T_Description", "Formula Added in test,
11   Test Name: " + tb.Rows(0)("T_Name").ToString())
12   cmd.ExecuteNonQuery()
13 connection.Close()
```

Figure 6. 42 Add Logs in Database

In above Figure 6.42 shows that when a user works with any event; an application will add log at the same time with parameters like User ID, Username, Date time, working with some description. Some examples are as shown in Figure 6.41. The log is a non-functional feature developed in our LIMS web-application to trace the user accessibilities as illustrate in section 5.5.

6.10. Application Language Translation

Globalization

Globalization is the process of application design and develops an application in a different culture. Localization is the process to design and develop an application for a given culture and neighborhood. There is one folder generated with name resources. In this folder, different files are placed with different extension with resource name and its value. Nowadays, people prefer multi-language application because business becomes multinational and online. Because of international clients', application requires to be designed in multi-language [48].

Globalization work

In Globalization, more than one file is there with different resources and values. If we take a real example; our LIMS web application is developed in two different culture: one is Portuguese, and another is in English. English is an international language, but the client needs this application in their own local culture because the company staff prefers local language to maintain laboratory data.

Different culture works

When a user opens an application, a system detects local culture and displays the content in their own culture. Moreover, it also depends on the browser language. In Portugal, almost all web application is developed in a local language and because of the local culture influence, all applications are available in the Portuguese language. However, this globalization works with the browser default language. Eg. Our web application is mainly designed in the English language as discussed earlier. Also, as explained above if the browser language detects the Portuguese

language then Globalization resource file fetch resource values from the pt resource file. If the browser language is English, then it will detect application language from the en culture file and display application content in that language.

How resource can call into the code to detect browser language and call particular language file and display resource value in a specific language.

```
1 <%$ Resources: Global, Home %>
```

Figure 6. 43 Application Translation

In given code Resource is a default setting to call resource file path from the project and Global because in our project the resource file name starts with the name Global. Now there are two files in our project code: one is with .pt extension and another is .en extension. When a user opens a browser default language will detect from the browser in a resource file an application will set application automatic in that language. Now the question will arise if the browser language is a different from the one which resource file is not available then? That time application will display a web page in a default language. In our application the default language is English, and another local language is Portuguese. If the user opens this application in Spain with Spanish browser, then an application language will be English because there is no resource available for that language. So, the application development will detect default language English and display application in the English language.

6.11. Responsive Design

As we are designing this application to be responsive; a user can use this application on different devices. Bootstrap is a framework, using bootstrap we can develop responsive and which is adjustable in any device. Bootstrap is in demand as of now in current market for responsive design, as it is easy to learn, and implementation is also straightforward. Using Bootstrap, we can reduce the web page design code because only by setting up the class in HTML tags; web page adapt design automatically. We only need to put standard tags which we are using in HTML to design a web page as discussed in development requirement section. When we download the bootstrap framework from the bootstrap website it provides some .css files with the JavaScript files and some are images which are required in designing. Bootstrap framework structure is illustrated in Figure 6.44 below:

```
bootstrap/
├── less/
├── js/
├── fonts/
├── dist/
│   ├── css/
│   ├── js/
│   └── fonts/
└── docs/
    └── examples/
```
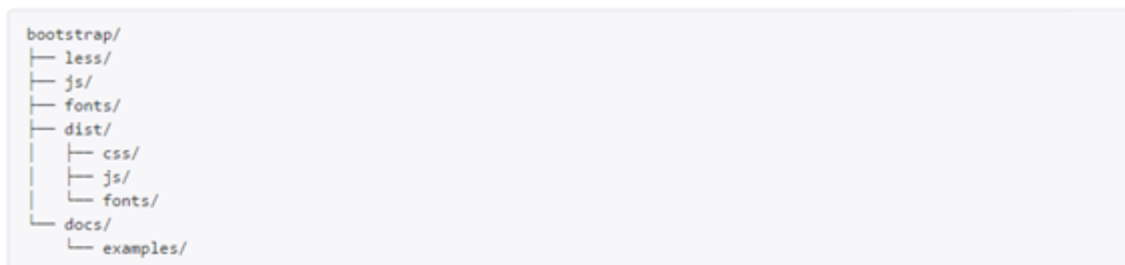
Figure 6. 44 Bootstrap Framework Folder Structure

In order to make our web page with the responsive design, we need to include bootstrap and CSS files in our HTML page header. After adding these files into the HTML page, it is required to add classes to the HTML tag. Bootstrap make this design responsive and automatic. Also, it puts

bootstrap default color for the different model. We also can make changes as per our requirements into the JavaScript and CSS files. Different icons are available, so it is not required to download and put extra images into the folder. The bootstrap framework also helps us to reduce the load on a web-page.

6.12. Reports

An issuing error-free report is the main aim of any laboratory. Only error free report generation is not the primary purpose but also due to waste of time and resources of an employee in correcting small mistakes which can happen every day. This dynamic system generated reports with dynamic results, which helps to save time and resources too. If any changes require in reports because of test result change, it is also possible to create a new report and generate a new report by some click in this web application. Our LIMS application provides export reports in a digital format for a specific time frame. The resulting file can send via email to the customer.

Following Figure 6.45 shows look and feel the dynamically generated report. In this report we can see the company name, a sample tested for, test name with all fields and results tested in the laboratory. Report with some information like report generated person, sample test starts and due date, sample name and its barcode. At the end of the report, one download button is available and we can download this report in PDF format.

Figure 6. 45 Sample Report

The Figure 6.46 shows that how a report data fetching is done from the database and how to manage in a web page. The table name has T_RESULT_DATA stores all data of result; the following snippet of code gets the report data by that unique id of a particular result. Initially the application will check the condition for parameter (starts from line no 4) in Figure 5.46 and print that result on a web page after that; prints the results value and at last point it will check the values

with the condition and original value added by an admin if it matches the condition it will print "ok" otherwise "not ok". This ok, not ok will prove that the result of this sample is under criteria or out of criteria.

```
1 Dim userDataAdapter2 As SqlDataAdapter = New SqlDataAdapter("SELECT * FROM
2 T_RESULT_DATA WHERE T_Unique=" + uniq, connection)
3 Dim userDataSet2 As New DataSet()
4 table2.Fill(userDataSet2, "T_RESULT_DATA")
5 For Each row As DataRow In table2.Rows
6    If row("T_Condition") = "le" Then
7       condition = "Lessthen or Equal"
8    ElseIf row("T_Condition") = "ge" Then
9       condition = "Greaterthen or Equal"
10   ElseIf row("T_Condition") = "bt" Then
11      condition = "Between"
12   Else
13      condition = "-"
14   End If
15   If row("T_FinalResult") = "0" Then
16      finalresult = "-"
17   ElseIf row("T_FinalResult = "0" And row("T_Condition") = "yn" Then
18      finalresult = "-"
19   Else
20      finalresult = "Ok"
21   End If
22   Else
23   If row("T_FinalResult") = "1" And row("T_Condition") = "na" Then
24      finalresult = "-"
25   ElseIf row("T_FinalResult") = "1" And row("T_Condition") = "yn" Then
26      finalresult = "-"
27   ElseIf condition = "Lessthen" Then
28     If row("T_Value") <= Between1 Then
29        finalresult = "ok"
30     Else
31        finalresult = "Not ok"
32     End If
33 Next row
```

Figure 6. 46 Report Generate

6.13. Analyze Results

Nowadays web application has become smarter because they can manage a client, product, sample, test, test result data, even user can analyze data in different ways and also filter data as per their requirements. This way user can get the result on a webpage, and without downloading the data from a webpage to word or excel file, a user play with it to get the desired results. Sometimes a laboratory requires to test that their result for a particular test is going ok or not. Also, they can compare the results of one test with another and can check the improvement of tested samples.

In our LIMS web application, a user can analyze the test results and manipulate it differently. On this analyze page, a user can filter the data company wise because our application mainly depends upon the company (clients). The client has products and product has samples which need to be tested and get the reports. Products are always present in the market for sale after doing different testing. These kinds of laboratories are having lots of sample, test and their results, which is difficult to manage by using the excel sheets and on paper.

The Figure 6.47 illustrates the results of a particular sample filtered between two dates. This analysis result page will allow a user to select the client initially, once a user chooses the client; the application will list out only that samples which is related to that selected client. After select client, the sample application will filter the data for the only chosen sample and list out the single test which is applied for that sample and at the end application will display the results of a selected test. Our app will allow a user to find an average, mediation, min-max value of filtered result too. This way a user can analyze full-year results for a particular sample or test for a single client. This feature also helps the laboratory to improve quality.


Figure 6. 47 Analyze Test Result

6.14. Front-Office Dashboard

This front-office can touch the user/customer/client. The front-office things are like UI/UX where the business happens.

<u>Dashboard:</u>

The dashboard comes with the more advanced features. A well-designed dashboard can save a vast amount of time and help a user to identify the number of operations quickly, to make an insightful observation or to compile reports easy way. The dashboard only provides direct access to any feature available in the whole web application.

After login as a standard user application will redirect on front office dashboard. In this dashboard application will display the overall status of the whole system. The front office dashboard will present an overall number of clients, the total number of sample, test, and products. The Figure 4.48 illustrates that the user will redirect on the list of sample, test, client and product pages. The regular user can see only client and product list, but they cannot make any changes in a data of clients and products; only an admin user has access to make changes in that data.
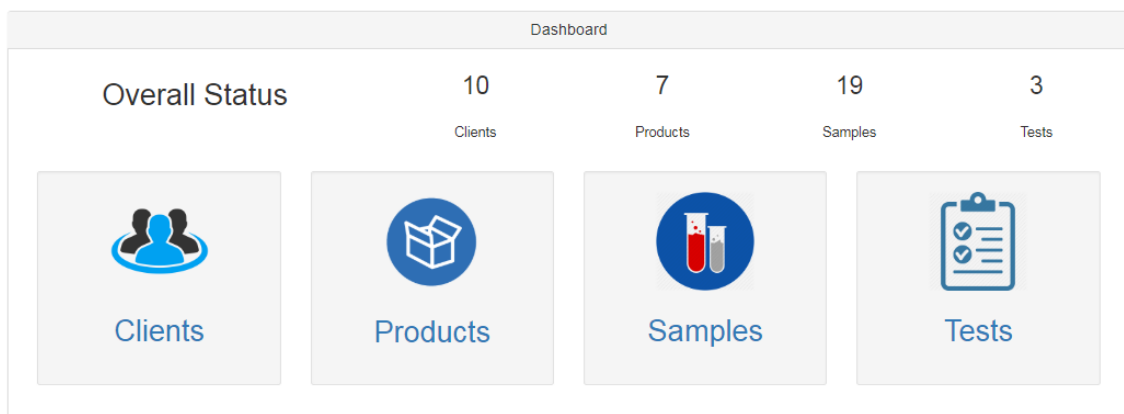
Figure 6. 48 Front Office Dashboard

After login in a front office, a user can see the list of pending tests. The Figure 4.49 is showing the pending test list with the Sample ID, Company Name, Sample Name, and Test Name with Add result or Delete test button. A user can delete this applied test to the sample and add a result for this test directly from the dashboard.

Initially, it is required to find a test which has no result inserted. The Figure 6.49 illustrate query for search an id of a unique test from "form id" of the test, if the test is applied then it will not show you in that list.

```
 1 For Each row As DataRow In testtable.Rows
 2   Dim a As String = "SELECT * FROM T_RESULT_DATA where FK_TESTID ='" + row("T_FormID").ToString + "'
 3                     AND T_SampleID ='" + row("FK_SAMPLEID").ToString + "'"
 4   Dim userData As SqlDataAdapter = New SqlDataAdapter(a, connection)
 5   Dim userSet As New DataSet()
 6   userData.Fill(userSet, "T_RESULT_DATA")
 7   tb = userSet.Tables("T_RESULT_DATA")
 8   If (tb.Rows.Count > 0) Then
 9     unique = tb.Rows(0)("T_Unique")
10   Else
11     unique = 0
12   End If
13 Next row
```

Figure 6. 49 Find Unique Test Pending Result

After finding unique id, the system will search for company name which is required to display in the pending test table. The SQL query presented in Figure 6.50.

```
 1 For Each row As DataRow In testtable.Rows
 2   'START SEARCH COMPANY NAME
 3   Dim b As String = "SELECT * FROM T_PRODUCT where PK_PRODUCT =" + row("T_ProductID").ToString
 4   Dim usrData As SqlDataAdapter = New SqlDataAdapter(b, connection)
 5   Dim usrSet As New DataSet()
 6   usrData.Fill(usrSet, "T_PRODUCT")
 7   tb1 = usrSet.Tables("T_PRODUCT")
 8   'END SEARCH COMPANY NAME
 9 Next row
```

Figure 6. 50 Search Company Name

Figure 6.51 shows the SQL query to find the sample status. If the sample is active or inactive, only an admin user can enable/disable a sample, and if a sample is disabled, it is not required to display the deactivated sample on the dashboard pending test list.

```
 1 For Each row As DataRow In testtable.Rows
 2   'START Check Sample Status Active or Deactive
 3   Dim d As String = "SELECT * FROM T_SAMPLE where PK_SAMPLE =" + row("FK_SAMPLEID").ToString
 4   Dim samplestatusData As SqlDataAdapter = New SqlDataAdapter(d, connection)
 5   Dim samplestatusSet As New DataSet()
 6   samplestatusData.Fill(samplestatusSet, "T_SAMPLE")
 7   sstatus = samplestatusSet.Tables("T_SAMPLE")
 8   Dim add_test As String
 9   Dim AlertDelete As String = GetGlobalResourceObject("Global", "DeleteAlert").ToString()
10   Dim AddResult As String = GetGlobalResourceObject("Global", "AddResult").ToString()
11   'END Check Sample Status Active or Deactive
12 Next row
```

Figure 6. 51 Sample Active / Inactive

The following snippet will display the pending test with the sample id, company name, sample name, test name with the action delete test and add result directly from the dashboard.

```
1 Dim userDataAdapter2 As SqlDataAdapter = New SqlDataAdapter("SELECT * FROM T_RESULT_DATA WHERE T_Unique=" + uniq, connection)
2 Dim table2 As DataTable = userDataSet2.Tables("T_RESULT_DATA")
3 For Each row As DataRow In table2.Rows
4   If row("T_Condition").ToString() = "le" Then
5     condition = "Lessthen or Equal"
6   ElseIf row("T_Condition").ToString() = "ge" Then
7     condition = "Greaterthen or Equal"
8   ElseIf row("T_Condition").ToString() = "bt" Then
9     condition = "Between"
10  Else
11    condition = "-"
12    Range = "-"
13  End If
14
15  If row("T_FinalResult").ToString() = "1" And row("T_Condition").ToString() = "na" Then
16    finalresult = "-"
17  ElseIf row("T_FinalResult").ToString() = "1" And row("T_Condition").ToString() = "yn" Then
18    finalresult = "-"
19  ElseIf condition = "Lessthen" Then
20  If row("T_Value") <= Between1 Then
21    finalresult = "ok"
22  Else
23    finalresult = "Not ok"
24  End If
25
26  Next row
27
28 End Sub
```

Figure 6. 52 Display Pending Sample List

Finally, the pending test list will look like Figure 6.53 with search and export features.

Sample ID	Company Name	Sample Name	Test Name	Action
1	Web Tech LDA	Agua	R1	Add Result ✖
1	Web Tech LDA	Agua	Controlo de inspeção	Add Result ✖
Sample ID	Company Name	Sample Name	Test Name	Action

Pendign Test — Copy CSV Excel PDF Print — Search:

Showing 1 to 2 of 2 entries — Previous 1 Next

Figure 6. 53 Pending Test Table

A sample has a different type of stats we have discussed earlier in this thesis sample module. We are setting up the status as per the change of sample status. Initially, we are storing the value of sample status as 0, if the user adds the result for the sample, the system will modify the value of sample status to 1. This way it becomes effortless to find out the pending sample with the status. Figure 6.54 displays the SQL query to find out the pending sample who do not have test results.

```
1 Dim testDataAdapter1 As SqlDataAdapter = New SqlDataAdapter("SELECT * FROM T_SAMPLE WHERE T_Status = 0", connection)
2 testDataAdapter1.Fill(testDataSet1, "T_SAMPLE")
3 For Each row As DataRow In testtable1.Rows
4    Dim duedate As Date
5    duedate = row("T_SampleDueDate").ToString()
6
7    If duedate < DateTime.Now.ToString("yyyy-MM-dd") Then
8      data1.InnerHtml = data1.InnerHtml + "<tr><td>" + row("T_ID").ToString() + "</td><td>" + row("T_OrderID").ToString()
9      + "</td><td>" + row("T_SampleName").ToString() + "</td>"
10   End If
11   data1.InnerHtml = data1.InnerHtml + "</tr>"
12 Next row
```

Figure 6. 54 Find Pending Sample List

Finally, the pending sample list will look like Figure 6.55 with search and exporting features.

Delayed Sample

Sample ID	Company Name	Sample Name
1	Web Tech LDA	Agua
2017001	aemiteq	Soft Water
2017002	aemiteq	Soft Water
20170003	CTCV	Soft Water
20170004	Web Tech LDA	Soft Water
20170005	aemiteq	Soft Water
20170006	Web Tech LDA	Soft Water
20170007	CTCV	Soft Water
20170008	aemiteq	Soft Water
20170009	Web Tech LDA	Soft Water
Sample ID	**Company Name**	**Sample Name**

Showing 1 to 10 of 19 entries

Previous 1 2 Next

Figure 6. 55 Delayed Sample

6.15. Back-Office Dashboard

The back-office provides tools that a company uses to offer services for a business process.

<u>Administrator</u>

In the back office, admin user is also able to filter the company product data using company dropdown. In the year drop-down, it only indicates those years which year has samples available. In which year samples are not inserted; the system will not appear that year in the dropdown list. In this admin dashboard, the same functionality is there like analyze the page. Initially, we need to select the company name after that only user can choose product name and vice versa for other dropdowns.

Different charts are available in the back-office dashboard page. All charts are designed and developed with the values of sample, product, and results. Also, showing different data for a specific year with varying results. These charts are generated and designed as per the client requirement.

<u>Sample Chart</u>

In the back-office dashboard, a bar chart shows the total number of samples available in a specific year. Also, it displays how much samples are inserted every month in that specific year. When data filters for a different company, all charts will load data for a selected company from the database. It will appear particular products of a selected company, after selecting a specific product the system will load all data related to a selected product from the database. At last, the system allows a user to select a specific year, and data will filter for a specific year from the database and display it in a chart view.

Figure 6. 56 Yearly Sample Chart

Above bar chart (Figure 6.56) shows the sample data for a selected company named Aemiteq; with filtered product water for the specific year 2017. A chart will show a total number of samples to an admin user. It is just a demo chart with demo sample data to understand filter functionality. This demo chart shows that only one sample is available in the month of September from Aemiteq company for product name water in 2017.

Study & Development of LIMS Web Platform Application

Overall Test Pie Chart:
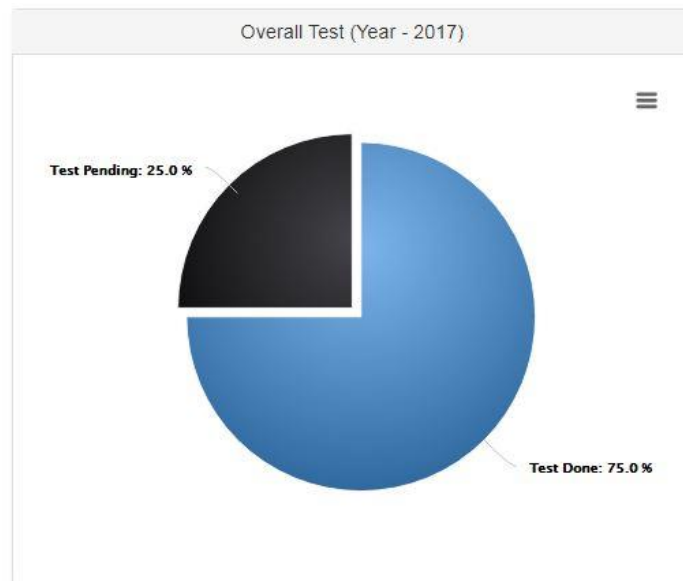
Figure 6. 57 Overall Test for Particular Year

Above pie chart (Figure 6.57) displays the overall (pending / done) test results details for a selected year (2017). This pie chart helps admin to find out an overall result of tests for a specific year. Above pie chart shows that 75 percent of tests completed with the results, and 25 percentage tests are pending with the result. It means seventy-five percentage tests are finished in 2017 and only twenty-five percentage tests are pending to test.

Overall sample Pie Chart:
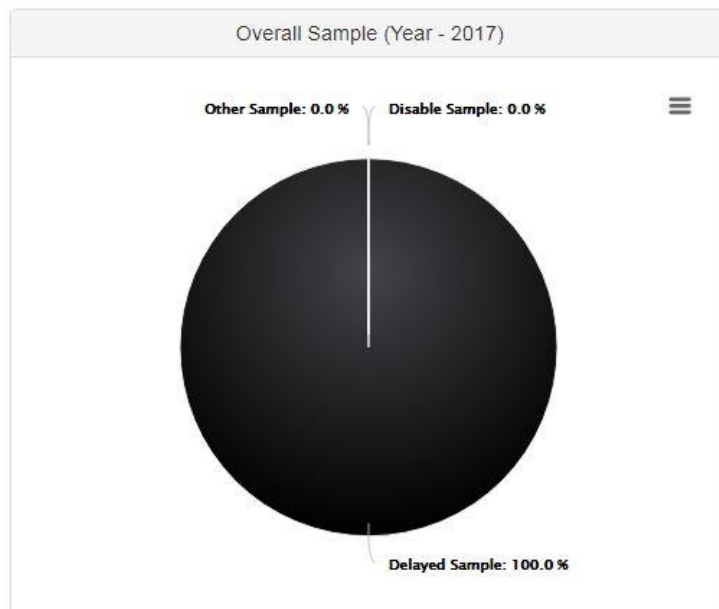
Figure 6. 58 Overall Sample for Particular Year

Above chart (Figure 6.58) show that hundred percentage samples delayed; because the due date of a sample is already passed the due date. This chart helps admin to find out a percentage of the

disabled sample and other samples. This chart data filter from the database using the sample status; as we explained above. Different charts are generated with the dynamic data; to display these dynamic charts, we have used the JavaScript framework named highcharts [49]. This JavaScript framework provides dynamic charts; it is required to set the values and chart type at defined places and the data will appear in chart format which is more reliable in comparison of numeric data. The Figure 6.59 illustrates the example code to design the pie chart on a webpage.

```
1 Highcharts.chart('pendingdelayedtest', {
2   chart: {
3     plotBackgroundColor: null,
4     plotBorderWidth: null,
5     plotShadow: false,
6     type: 'pie'
7   },
8     title: { text: '' },
9     tooltip: { pointFormat: '{series.name}: <b>{point.percentage:.1f}%</b>' },
10    plotOptions: {
11      pie: {
12        allowPointSelect: true,
13        cursor: 'pointer',
14        dataLabels: {
15          enabled: true,
16          format: '<b>{point.name}</b>: {point.percentage:.1f} %',
17          style: { color: (Highcharts.theme && Highcharts.theme.contrastTextColor) || 'black' },
18          connectorColor: 'silver'
19        }
20      }
21    },
22    series: [{ name: 'Percentage',
23      data: [ { name: TestDone, y: parseInt(done_test) },
24      {
25        name: TestPending,
26        y: parseInt(pending_test),
27        sliced: true,
28        selected: true
29      }]
30 });
```

Figure 6. 59 High Chart Configuration

Above code is a sample code to design a "Pie" chart. We have defined the unique id "Pendingdelayedtest" to display only pending and delayed test in this "Pie" chart and pointFormat variable set as a percentage to display data in a percentage format. The same way we can design bar and different charts with given JavaScript sample code.

The system needs an appropriate title to understand where the user is at that time. A user is not going to work with this kind of application longer and without a meaningful title, user become confused where he/she is and what they were doing with the LIMS application. Sometimes a user needs to works simultaneous with a different system if a user forgets that, what he was doing on that page; he needs to begin their work again from scratch.

Another thing is sample status; if every sample does not have status, then it will become more challenging to manage a sample data. To make it easier to manage whole data and filter as per requirement, the system used to store sample status in a database table with sample details like finished, and ongoing. If a sample will have a test and all test are done with the results, a sample status must change as a finished sample. If a sample is in the same position as at the time of inserting sample data without any test or sample result, it will store with the ongoing status. Different sample status will help a user to manage samples easily.

7. Conclusions and future work

This internship report explains the design and implementation of a Laboratory Information Management System (LIMS) in detail. This system is developed as a web application to maintain remotely, for management of small laboratory data which is designed for the control of samples, tests, reports and the user profiles. The system allows searching information very quickly. The use case diagrams are designed with fully detailed Use Case documents for all two parts (Sampling and Testing) of applications in the analysis phase. In the design phase, an architecture is defined and a database diagram is designed which describes the documented object and information structure. During the implementation, an appearance of web pages is defined using CSS while JavaScript and jQuery are used for client-side scripting. The whole system is tested and bug tracking and source control is hosted at the CTCV testing server.

As mentioned previously, every laboratory requirement changes rapidly, because of this reason some extra work must be required in the future. The user access level needs to improve for more security reasons. Other features like sending reports to the client via electronic way and a client can receive it immediately. Also, a client can provide feedback on that report. In the future, we have also plan to demonstrate our software to small laboratories and could get basic requirement of the small laboratories and even some ideas to improve our LIMS software. Also, we can create a standard client account and provide them access to see the test and result of a specific sample and test. If a client has direct access to view the results, it could save time to generate a report of examination and send it to the clients. Finally, we can grow an online business, and save time which small laboratories are wasting on paperwork and submitting reports to the customer.

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