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Review

Trends in laboratory information management system

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ABSTRACT

Laboratory information management systems (LIMS) is designed considering the need of analytical laboratories to carry out the research in fast, efficient and transparent manner with better accessibility of the instruments.

Its development started as an in-house project then moved to custom built solutions followed with open source LIMS, first LIMS were developed in the pharmaceutical and related industries for use as a Quality Assurance/Quality Control (QA/QC) tool in the early 1980's by in-house development departments or under contract by external software houses. Further, it is commercially developed by using the latest tools in information technology and based on the need of the laboratory it has got many varieties. Various sectors like agriculture, environmental and water, food and beverage, manufacturing, product quality and cyber forensic analysis etc. uses full-enterprise LIMS in their operations. It was found that the LIMS applications are not running properly due to its limitation such as improper installation, poor implementation, lack of technical access etc.

This paper highlights the review of developmental stages of LIMS and some shortcomings for attaining the total quality management in a laboratory that ensure efficiency, enhanced productivity, better utilization of resources and security measures etc. An effective management system totally depends on the laboratory infrastructure. Hence, proper study of the laboratory functionalities is required before going ahead with the solution.

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1. Introduction

An information system (IS) as defined [35] is a combination of information technology and people's activities for the best throughput. In a very broad sense, the term IS is frequently used to refer the interaction between people, processes, data and technology. A management system is the framework of processes and procedures used to ensure that an organization can fulfill all tasks required to achieve its objectives [1].

A management information system (MIS) helps organization for effective management [17] which involves three primary resources: technology, information, and people. In order to study the better management system, all the three resources must be recognized where the people is an important resource. MIS is regarded to be a subset of the overall control procedures in a laboratory or business.

Presently laboratories around the world depend on a management system to manage data, inventory and assign rights. LIMS is a

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software utility that was developed in-house by organizations who wanted to improve the data acquisition and reporting processes. IS is based on the continual availability of the data which is further sorted and organized into various reports based on the requirement. A full-featured LIMS manages various lab data from simple log-in to reporting the results.

Till the late 1970s, management of laboratory samples, associated analysis and reporting were time-consuming and error prone due to manual processes. Hence some organization geared up with the different mode of data collection and reporting while some enterprising entities started developing commercial reporting solutions in the form of instrument-based systems. A need for a more effective system felt and a next stage of LIMS started developing [9]. User defined custom-built systems became available with good features at that time. These systems were solutions designed by independent systems development companies to run in specific laboratories.

Custom-built LIMS and commercial LIMS were started developing in parallel and this extensive research effort resulted in the first commercial solutions that were formally introduced in the early 1980s [7]. LIMS for sample process and data management are as numerous and varied as the companies that use them.

2. Theoretical development

Initially the LIMS were developed in the pharmaceutical and related industries for use as a Quality Assurance/Quality Control (QA/QC) tool in the early 1980's by in-house development departments or under contract by external software houses. Such commercial LIMS were proprietary systems, often developed by analytical instrument manufacturers to run on the instrument. These LIMS were exclusively based on a minicomputer or mainframe technology, often using proprietary database software as their base.

Table 1 shows the detailed journey of LIMS starting from 1980's till date. In 1980's laboratory notebooks and handwritten reports/charts were used to track and report information. In-house IS was configured by technologically-adept laboratories where custom-built LIMS became available from third-party vendors. In 1982 the first commercial LIMS known as first generation (1G) LIMS were introduced in the form of a single centralized minicomputer, offering automated reporting tools. Second generation (2G) LIMS came in 1988 and used relational databases for specific application solutions, it was depended on minicomputers. Third Generation (3G) LIMS came in 1991 basically on open systems, combining the PC's easy to use interface and standardized desktop tools with the power and security of minicomputer servers in a client/server configuration. Client/server architecture divided the data processing between a series of clients and a database server that runs all, or part of, the relational database management system (RDBMS) [2]. A LIMS was developed as part of the Human Genome Project for genome research carried out by an international consortium and they found it as an essential tool for advanced studies in the life sciences [16,25]. Fourth generation (4G) LIMS came into the picture in 1995 focusing on decentralizing the client/server architecture and optimizing resource sharing and network throughput by enabling process to be performed anywhere on the network. Thus, all clients and servers could operate at capacity depending on the data load at any particular instance [2].

Web-enabled LIMS were introduced in 1996 with wireless computing capabilities where as in 1997 due to US FDA CFR Part 11 rules on electronic records and signatures, LIMS started with the new electronic signature function. Web-enabled Global Positioning Satellite (GPS) technologies for georeferencing sample location at the time of sample collections were introduced in LIMS in the year 1998 also XML recommended in industry as application-specific markup languages, such as Chemical Markup Language (CML). First Application Service Provider (ASP) introduced in LIMS in 1999 that could be purchased on a monthly basis and accessed over the Internet via a secure line from the LIMS vendor and first completely XML-based LIMS on Microsoft's .NET platform was introduced in 2002 [42]. During 2003 a relational database laboratory information management system (RDLIMS) for managing the personnel, facilities, equipment, and instruments was developed. Emphasis had been placed on assuring personnel safety while utilizing such systems at the critical remote locations. Built-in mail system was there that allowed communications with personnel based on a wide range of sorting choices including user classification, facility and instrument access rights. The LIMS gathered information from an unlimited number of computers in an unlimited number of widely separated facilities over a distributed computer network using TCP/IP communications over LAN and a Microsoft SQL 2000 Server. The user accessed the custom programs via protected WWW access to pages generated in HTML and with active server pages (ASP) from a Microsoft IIS server. VB programs and the ASP pages were developed in a highly modular form with security controls. FTP, HTTP, and SQL were used for multiple levels of backup [5,14].

Different LIMS were available in the market till 2004 however they did not fulfill all requirements regarding flexibility and process connectivity. The main focus was on fully web oriented LIMS model based on modern web oriented software technologies which included planning tools, a virtualized lab, and on-line process adaptation as well as an interface for computational data processing and data mining [36–40].

LIMS developed in 2005 have used open-source software, PHP and MySQL. PHP is a hypertext processing language that is well suited for our web-based approach; MySQL, the open source database, forms the backend of LIMS to manage the associated information. The advantage of the open-source community is the ability to share application knowledge that is readily transferable to fellow developers; currently many PHP applications are freely available on the Internet [6,32,4].

In 2006, the requirement for LIMS with secure, flexible open database connectivity (ODBC) was needed to build a complete, protected electronic tracking system and to maintain records [39]. LIMS available during this time were implemented in a JAVA program and PostgreSQL database [10].

Table 1
LIMS development with milestone.

Year	Milestones in development of LIMS approach
1980–1995	In-house development to 4th Generation LIMS [2]
1996–2002	Web enabled to XML based LIMS [42]
2003	A relational database laboratory information management system (RDLIMS) [5,14]
2004	On fully web oriented LIMS model based on modern web oriented software technologies [36–40]
2005	Used open-source software, PHP and MySQL [6,32,4]
2006	Implemented in a JAVA program and PostgreSQL database [10]
2007	Simplify web automation, and integrate application within or between organizations [10,11]
2008	Robust LIMS for the efficient handling of data [15,24]
2009	Most user friendly interfaces of LIMS [8–44]
2010-till now	LIMS is more focused on providing a user-friendly and integrated data management solution [43]