Laboratory Information Management System

by

Jay N. Meegoda, Ph.D., P.E.,
Department of Civil and Environmental Engineering

and

Chi Tang, Ph. D.
NJ Institute of Transportation

New Jersey Institute of Technology
Newark, NJ 07102

NJIT Project Nos. NCTIP 992505, NJDOT 995925
Task No. NCTIP-34

January 2002

Interim Report on Research Sponsored by the
New Jersey Department of Transportation
and
National Center for Transportation and Industrial Productivity
Material Information Management System

ABSTRACT

A computerized Material Information Management System (LIMS) is developed. This intranet-based information management system is a state-of-the-art research project where material engineers working closely with computer and operations research specialists to develop a comprehensive and fully functional Material Information Management System for the New Jersey Departments of Transportation (NJDOT). It reduces the paper-workloads significantly and provides the capability to organize relevant data rapidly. The implementation of LIMS also shortens the time between project completion and final closeout mandated by the federal highway administration for federally funded projects. The project has a great potential to be a showcase for the nation and to be applied by other state Departments of Transportation.

INTRODUCTION

The New Jersey Department of Transportation (NJDOT) has taken a leadership role in developing computerized database information management systems. It has been recognized that needs exist to: a) reduce paperwork, b) expedite the material approval process, c) shorten the time between project completion and final closeout, and d) analyze the functional relationships between material testing data and material performances in order to identify significant trends in time.

Currently, most material test results are applied on a micro scale and paper-filed. To integrate the operational functionality of the material data filing, processing, and transfer, a computerized local/remote Intranet network management system should be developed. This system will standardize the data entry procedures, define performance evaluation measures, certify material test data, analyze the relationships between testing data and actual material performance, streamline the project closeout process, generate summary reports, and be able to communicate with NJDOT existing information systems, such as PMIS. Fully developed, it is envisioned that the system will connect 20 field offices, 3 regional offices, and the central office in Trenton to transfer information, trail material samples, and periodically replicate the material database. During an evaluation period, both the current paper-based filing system and the electronic intranet-based LIMS will work side-by-side as co-existing systems. Eventually, LIMS will replace the current system.

SYSTEM CONFIGURATION

NJIT research team is using a server based on Intel chip (low cost) with Windows NT operating system (security) and SQL database (graphical interface using Visual Basic). During the first phase of this project, NJIT research team
would install a primary domain controller (PDC) running Windows NT with SQL server in the Trenton office or the head office. NJIT research team will finally implement the project on a dedicated directory in the NJDOT NT server. During the second phase of this project, another server will be utilized in the North region as a backup domain controller (BDC). A computer running Windows 98 in one field office selected by NJDOT bureau of material will be connected to the PDC via a 56K.V90 modem pool or digital subscriber line (DSL). NJIT research team will provide instructions for adding two more BDC for the remaining regional offices. Figure 1 shows the computer configuration when the system is fully implemented. The PCD and BDC should have the capabilities of disk duplexing and tape backup support to maximize the reliability and fault tolerance of the network. In order to manage the vast amount of data, NJIT research team plans to develop a way to archive the data older than a specific time, say five years.

The Microsoft SQL server version 7.0 has reduced administrative overhead from its current version 6.5 and hence SQL version 7.0 is be used in this project. Many server configuration options have been simplified in SQL version 7.0. For example, a database increases allocated resources when necessary without ever committing them and decreases the resources used when they are no longer needed. The SQL 7.0 databases now reside on operating system files instead of on SQL Server logical devices. Database files can expand automatically, eliminating the need for administrators to make manual adjustment of these settings.
SQL Server 7.0 works with Windows NT Workstation and Microsoft Windows® 95/98 as well as Windows NT server. The SQL version 7.0 accessed using Windows 95/98 is fully featured except for a few limitations imposed by the operating system. For example, SMP, named pipes, full-text search, asynchronous I/O, and integrated security are not supported on Windows 95/98. However, this will not hinder the LIMS performance if the system design avoids using these limitations.

In addition, SQL Server provides a host of new features for data warehousing. Summarized information can be stored in data warehouses for analytical applications to use conveniently. Furthermore, using Microsoft English Query, a development tool gives users the ability to query a SQL Server database in natural-language (English) questions, users can obtain information about particular tables, fields, and data of the SQL database without having to know how to write query statements.

RESEARCH SCOPE

Currently, there are more than 110 forms, reports, memos, and labels and cards in use. Many of these forms have the same usage with different layouts. Each one of them has to be filed manually. It is a very time consuming and labor intensive process. Also, the transfer of these documents among related units of NJDOT causes delays in decision making. The Material Information Management System (LIMS) will streamline and simplify the entire filing procedure of the Bureau of Materials, thus relevant information will be integrated into an electronic data processing and management system automatically.

The design and the development of the LIMS system require considerable research efforts. The major study topics include:

1. How to identify and synthesize the operational logic and business rules in the material testing processes so as to search for the best ways to organize and unify the forms, reports, approvals and all relevant documents;

2. How to normalize the LIMS relational database (SQL) and apply Intranet techniques to secure data integrity and manage data flows within NJDOT existing networks;

3. How to convert and integrate the existing OIT electronic data for concrete cylinders;

4. How to handle data approvals and notification of approvals to appropriate users;

5. How to protect and archive the data;

6. How to accommodate both Metric and English units;

7. How to improve the system flexibility such that new materials and new information can be inserted;

8. How to minimize the data entry errors through cross checking;

9. How to minimize the routine workload and improve the efficiency of the data processing with customized client application programs; and
How to automate the filing processes and speed-up the closeout procedures by scheduled replication tasks and alert message service of the SQL server. In other words, the entire closeout procedure will be monitored by the system and the responsible person will be notified of the current project status.

The proposed SQL based LIMS system will support the following features when applicable:

- Registration integrity of material samples, products, customer and vendor specifications
- Multilevel limit checking for specification limits, warning limits, outer limits, and user defined limits
- Automatic calculations of compliance, penalties, etc.
- Automatic approval/validation of testing results
- Conditional event triggers and automatic electronic mail for testing results
- Incorporate penalty/bonus adjustments to project expenses
- Generation of summary reports
- Metric/English units conversion
- Bar-code reading support and label printing
- Direct data downloading from nuclear gage and concrete compression tester
- Instrument Maintenance/Calibration scheduling & recording

OPERATION PROCEDURE

The LIMS data entry is central to all samples no matter whether of raw material, in process, intermediate, or finished product. By LIMS design, the data entry can be done manually (basic information initialization), automatically (calculated and transferred results), or be triggered (data downloading) by other device.

Each sampling process has its own logical life from beginning to the end. All data entry forms in LIMS will be created according to their sampling logic and unified by their virtual usage. It is the integrated design of the sampling cycles that makes LIMS such a flexible and reliable information management system.

First, after the approval a sampling template form is filled by inspectors with the basic information such as project ID, job number, material type, testing date, location, producer, customer, inspectors and operators. This basic information needs to be entered into LIMS only once and can be automatically pulled up as part of any sampling forms in the future.

Second, laboratory supervisors outline the tests to be completed and field engineers and sampling workers will correspondingly generate specific worksheets from LIMS and will fill the necessary information after samples were taken for testing. Each sample is uniquely coded for identification using a user defined sample ID number. Using this information, all relevant data about the sample can be retrieved immediately at any stage of its entire sampling process form any location in the system provided the user has the required authority. The
sample-taking process is accomplished when the worksheets are returned to the local laboratory and the identification information has been entered into LIMS database.

Third, samples are tested at a local laboratory or sent to the central laboratory in Trenton with labels. Since all the sampling ID information has been input into the system, the labs can pop-up the required testing result form onto a computer screen based on the label received and fill the form with the tested results. LIMS will automatically check the specific limits and calculate the results so as to generate Pass/Fail reports immediately, and will calculate the pay factors. If all results pass specification, LIMS will recommend a sample completion status of Complies. Comments are entered in the event that a Conditional Approval status is assigned to a sample. Once the reports are generated, the local and central labs as well as other units of NJDOT will be able to use them for further analysis.

Meanwhile, other related operational reports, business memos, and closeout documents are also ready to be created by people in charge whenever the required information has been available in LIMS. LIMS will provide the capabilities of customized data querying, standardized report generation as well as comprehensive graphics utility to display result trends.

Finally, all the sampling data are secured in the relational SQL database with integrity for reliable and flexible retrieval and application. The schematic diagram for concrete cylinder tests shown below illustrates the operational procedure discussed previously.

The final prototype version of LIMS will accommodate test results for all 53 of the materials tested by NJDOT’s Bureau of Materials. Following, is a list of the highest priority materials.

1. Portland Cement
2. Portland Cement Concrete (Cast-In-Place)
3. Asphalt Cement (Asphalt Binder)
4. Bituminous Concrete (Hot Mix Asphalt)
5. Aggregate Sources (Coarse, Fine, & Mineral Filler)
6. Soil Aggregate
7. Dense Graded Aggregate Base Course (Virgin & Recycled Materials)
8. Structural Concrete (Prestressed Beams, Piles, and Noisewall and Precast Culverts)
9. Structural Steel Bridge Members (Box Beams, I-Beams, Diaphragms, etc.)
10. Asphaltic Emulsions
11. Asphaltic Oils (Cutbacks)
12. Concrete Deck Overlay Protective Systems
13. Concrete Pipe
14. GO & GA Signs (Overhead & Adjacent Guide Signs)
15. Guiderail Materials (Rail, Posts)
16. Overhead and Cantilevered Sign Structures
17. Paint – Structural  
18. Paint – Traffic (Epoxy)  
19. Precast Concrete (Retaining Wall, Noisewall, Inlets, etc.)  
20. Steel Reinforcement (Epoxy Coated Rebar and Spiral)  
21. Steel Reinforcement (Uncoated Rebar and Spiral)  
22. Welded Wire Mesh 

In this pilot-scale project proof of concept will be demonstrated where four major materials, namely concrete, soils, asphalt and steel will be included in LIMS. 

IMPLEMENTATION

![Schematic diagram](image)

**Figure 2**-The schematic diagram showing the implementation for concrete cylinder tests.

In order for proper implementation a mission statement was developed, based on which the LIMS is formulated. It is given below.

To provide a system for creating and gathering material related business and testing information about NJDOT material bureau personnel and facilities; contracts and awards; contractors, suppliers, producers and plants; product mix design; production quality control; field sampling operation as well as Lab. test results via Intranet of NJDOT Materials Bureau. Also this system should be able to generate analysis reports based on their collected information and maintain all relevant data documents in a SQL server database. Ideally, this system should
facilitate the management of material testing and project close out process via secured, user-friendly WebPages and VB 6.0 user graphical interfaces.

Figure 3 shows the flow chart for implementation for concrete cylinder tests. The research project is at the initial stages where the database is built to implement the testing of concrete cylinders, which certifies the fresh concrete poured. Based on tonnage used, the fresh concrete is the highest consumed material for NJDOT. Figure 3 is a schematic diagram showing the implementation for concrete cylinder tests. Figure 3 shows the flow chart for implementation with the pay factors for not achieving the specified concrete strength values. The other research issues incorporated in the database include the security of the system. Once an NJDOT employee is logon into the system based on the username the system assign the read, write, edit and delete privileges based on the position and the location of the user. For instance a technician entering raw data in a field office can only modify the data entered in that office. Once his or her supervisor approves the data no one is allowed to edit, modify or delete. For the concrete mix designs the existing database based
on FoxPro is already imported to SQL database and hence once the mix design ID is entered all the fields in the LB 201 form used for the concrete cylinder test.

CONCLUSIONS

Currently, most state department of transportation material test results are applied on a micro scale and paper-filed. Each lot is assessed separately for compliance, penalties, etc. All the test result reports are manually generated, distributed, and filed away individually. The filing processes of approving projects, preparing material test result reports, and searching relevant closeout paper-documents are very labor intensive and time-consuming. The need exists to replace the current paper-based filing and transportation system by an intranet-based electronic filing system. The needs also exist to streamline the process of approval and compiling federal highway agency closeout packages as well as to analyze the functional relationships between the testing data and the materials' performance. NJIT is currently developing a SQL based material information management system to computerize all material data. The project is at the initial stage where the database is ready to implement concrete cylinder tests, which is for the largest consumed material for NJDOT.

ACKNOWLEDGEMENTS

New Jersey Department of Transportation and National Center for Transportation and Industrial Productivity jointly sponsored this research. The program manager at NJDOT is Mr. Robert Sasor and for NCTIP is Dr. Lazar Spasovic. Although NJDOT and NCTIP funded the research described in this paper, it has not been subjected to both Agencies' review process for the technical content, quality assurance/quality control, or administrative review. Therefore, it does not necessarily reflect the views of both agencies. Authors would also like to acknowledge the NJDOT task force headed by Ms. Eileen Connolly and Mr. John Zim.