First International Conference on Construction in the 21st Century (CITC2002)
"Challenges and opportunities in Management and Technology
25-26 April, 2002, Miami, Florida, USA.

WEB-BASED TOOL IN PROJECT QUALITY MANAGEMENT

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ABSTRACT
The paper presents a state of the art application of web-based technology in providing an affordable system for managing project quality information. The advantages are demonstrated through a case study of a fully implemented quality information management system for a highway mega-project in New Brunswick Canada. The system developed addresses key needs including support for various levels of management (technical and executive), an open data structure and inter-operability, hierarchical information levels, integration with facility-wide management information, and future scalability. The developed system addresses the needs of quality information management for a private project developer but can also be adapted to other project delivery mechanisms. The tool was implemented to support the entire project team including construction field supervisors and project's senior management. The paper offers a documented analysis of a generic implementation process that can be adopted in other projects to improve efficiency in quality information management in the highway construction industry.

KEYWORDS
Web-Based Technology, Project Quality Information Management, Private-Public Partnership

1. INTRODUCTION

The concepts of quality management have been successfully applied in many industries, primarily manufacturing, and are equally applicable to the highway construction industry. As facility owners realise the benefits of a project delivered under a quality program, they will increasingly require a rigorous and effective quality management system as a condition of construction contracts. A significant barrier to successful implementation of a quality system is the increased information management requirements. This paper discusses the challenges, design, development and implementation of a web-based system to support the project information management needs.

Out of the need to deliver an effective quality management system, a web-based Quality Management Tool (QMT) was developed and implemented for the design-build-operate company by a team of researchers at UNB. The application tool had the following functional objectives: support for various levels of detail in storage, viewing, and reporting information; flexibility and scalability in set-up and use; an integrated approach to construction management information with an open data structure; and a comprehensive support for decision analysis with the ability to report on all current total project dataset.

2. WHY A QUALITY MANAGEMENT INFORMATION SYSTEM?

Providers and operators of public infrastructure have become increasing cognizant of the role of quality in meeting user, client or public satisfaction, reducing life-cycle costs, and achieving competitive advantage (Battikha, 2000). As-built quality has been shown to increase service life of the facility. In the paving industry for example, an NCHRP study demonstrated that pavement life was increased by up to 15 percent by increased quality in initial pavement smoothness (Smith et al, 1997). Apart from increased service live, lower as-built pavement smoothness has been associated with reduced vehicle operating costs, substantial environmental benefits, and road user satisfaction.

More immediate to the facility builder is the obvious fact that non-conformance or lack of quality is associated with costly penalties, increased costs and time for correcting the unacceptable work. To the eventual facility owner or operator, non-conformance results into increased maintenance costs, reduced safety from premature failures and repair work zones, and loss of customer/user satisfaction.

The need for an effective quality management system is critical in major facility projects in general and more so in design-built-operate highway *mega* projects. The organizational structure of most private-public partnership projects consists of the project owner, an agent of the owner, and a project developer's team comprising of project financiers, designers, builders, and an operation & maintenance company. Given the diversity of the parties and ensuing complexity of the contractual relationships, a quality management system becomes extremely important. The communication process with respect to quality issues in most mega projects tends to generate a large volume of information. The quality management system is thus critical in delivering the project with an acceptable quality, cost and time.

3. CHALLENGES OF QUALITY MANAGEMENT IN MEGA-PROJECTS

The construction industry is attracting newer project delivery mechanisms resulting into inevitable evolution in the manner in which project quality is managed. Two such recent trends are in the project specifications - the movement to end results specifications (ERS), and in the financing mechanism - the use of private-public partnerships.

The industry is evolving from method specifications or recipe type specification, towards end results specifications (ERS) or performance based specifications. The ultimate effect of such changes in project environment is a change in the traditional owner-contractor-consultant relationship, its role in facility design, quality control and quality assurance, and the distribution of risks and liability in the project delivery process. ERS contractual arrangements typically require the contractor to implement, during construction, a quality control system that ensures meeting minimum performance criteria over a specified time period. While such trend to ERS provides a positive environment for innovation and optimization from the construction industry, it also creates unique challenges to the industry. Issues include how to set achievable yet reasonable minimum performance standards, for example, as-built quality, work quality during maintenance, level of service during operation, etc.

Public-private partnerships (P3) are also increasingly becoming significant mechanisms for delivering public infrastructure projects in industrialized countries. Recent examples of P3 for highway mega-projects in Canada include the under construction Fredericton-Moncton Highway Project, Highway 407 in the province of Ontario, Highway 104 in the province of Nova Scotia and the Confederation Bridge linking the provinces of New Brunswick and Prince Edward Island.

The very complex relationship between the parties in a P3 project environment underpins the challenge to quality management. With the inevitable diversity of the parties involved, the process and ensuing complexity of the contractual relationships, a quality management system needs to meet the needs of multiple parties. Moreover, the communication process with respect to quality issues and conformance is likely to generate a large volume of information.

The performance-based contractual arrangements and the requirements for medium or long-term facility operation by a private developer create new challenges for quality management. The end results specifications (ERS) or performance-based specifications put the onus on the private developer to set appropriate standards and manage quality throughout the project delivery stages.

These trends have created a higher need for the developer to implement a comprehensive information system to manage the project quality and to provide rigorous support for conformance requirements. This is an excellent area for applying an information technology (IT) solution (Battikha and Russell, 1998).

4. THE CASE STUDY PROJECT

The case study is based on the just completed, Fredericton to Moncton highway project. The government of New Brunswick, Canada, issued a Request for Proposals in March 1997 to three proponents for submission of Technical Specifications, a Quality Management Plan, and Financial/Legal/Economic Plans. Within the Quality Management Plan, the owner required an ISO 9001 compliant Quality Management System for all aspects of the development, design and construction of the Project.

The principle project participants were: the owner – Fredericton Moncton Highway Project Company; the owner's consultant - Independent Agent; the developer - MRDC Construction Joint Venture, the designer - MRDC Engineers Joint Venture; and the eventual highway operator - MRDC Operations Corporation. Figure 1 shows the organization structure of the project emphasizing the key players responsible for the quality. Within the Developer, a full time Quality Manager supported by three or four quality engineers was responsible for quality of all the construction work carried out by various subcontractors. Several Field Supervisors resident on each project section supported each Quality Engineer. The field inspectors were responsible for work of subcontractors with respect to time, cost, quality, safety and environmental requirements.

As a method to measure the Developer's Quality Management System, the Independent Agent used a Quality Performance Score (Collier, Corbett and Lundrigan, 2001). Initially, this value was reported as the "Degree of Conformance" modified by deductions for certain classes of non-conformance (by cost of rectification) and failure to meet certain quality system requirements. In this scoring system, equal weight is given to all deficiencies and non-conformances. The score was calculated on a monthly basis and was tied to a Quality Management Performance Payment of approximately 4% of the Guaranteed Maximum Price for the Project (about $24 million in total). In order to qualify for the full monthly payment, the Developer had to achieve a score of 99 percent (Figure 2). This monthly payment scheme provided even more incentive for the developer to maintain an effective Quality Management System.

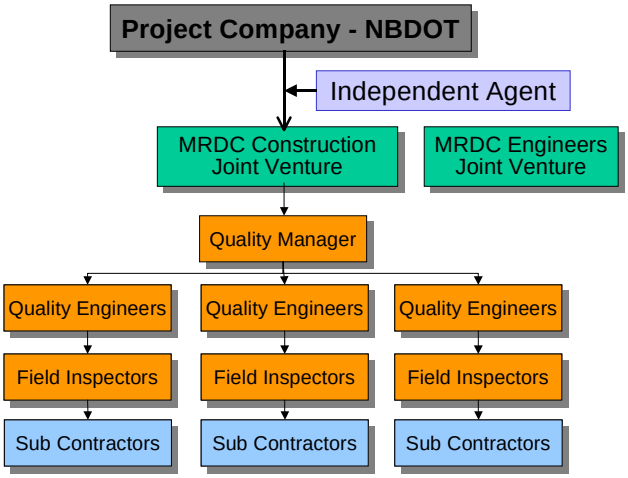

Figure 1: Project Organization Structure Responsible for Quality

Figure 2: Percentage of Monthly Payment for Quality Performance Score

5. DEVELOPMENT OF THE QUALITY MANAGEMENT TOOL

5.1 System Functionality

The web-based quality management tool was designed and implemented to support quality management processes following a system implementation that is compliant with ISO 9000 guidelines. The system's functionality was achieved through a combination of commonly accepted software application functions. The functionality include standard graphical user interface that addresses the special requirements of a quality management system. The system design and implementation was guided by: (a) Support for various levels of information detail, (b) Flexibility in set-up and use of the system, (c) An open data structure allowing efficient data sharing with other information systems, (d) Scalable or extendable, and (f) Multi-level users' support.

5.2 Application Development

The QMT development utilizes Internet technologies for data central archiving and distribution of construction project information in a secure environment. The underlying IT technologies include modular designs, efficient data conversion and compression formats, secure file storage and accessibility, and efficient organization and indexing of project information. The QMT is a web-based collaborative system founded on the concepts of previously developed systems but has been adapted for specific application in the support of quality, safety and environmental construction information for a public-private partnership *mega* highway project.

The application model of the Collaborative Project Environment (CPE), a web-based collaborative construction management system was used as the basis for the QMT's interface and data structure. A detailed needs analysis for the Developer – MRDC was performed from which the system was designed to meet the requirements for the various processes, data, and interface structure.

5.3 QMT Process Analysis

The QMT process framework was implemented from the extensive needs analysis of MRDC's quality personnel. In relation to Quality for example, Quality Assurance Engineers were responsible for quality performance of sub-contractors' work. They carried out regular Quality Audits, independently or as follow up of Field Inspectors reports. Non-acceptable elements identified by Field Inspectors or Quality Engineers are classified as Deficiencies and Non-Conformances. The non-conformance report (NCR) remains open with the QMT until a corrective work has been successfully completed. It other words, QMT was critical in identifying, documenting, and tracking successful rectification by the responsible contractor. Upon completion and verification of the corrective action, the appropriate quality assurance engineer will enter a formal close out in the QMT records.

5.4 Software Implementation Framework

QMT was developed for a highway *mega*-project; however, the goal was to make it equally applicable to small and medium sized construction companies. The software and hardware requirements and implementation scheme were selected with this consideration in mind. Figure 3 depicts the overall architecture for the system. Two software

applications — Allaire's Cold Fusion® and Microsoft's Access® — were used for development and the resulting tool is hosted on a server running Microsoft's Internet Information Server®. For scalability reasons, conversion of the database to Microsoft's SQL Server® is being considered. Figure 4 shows an overview of QMT functionality of the user interface. The technical details of QMT's user interface, system protocols, data structure, navigation procedures, security features, etc. are discussed in (Rankin, Christian and Lundrigan, 2001, Rankin et al, 2001).

5.5 Challenges and Lessons from Implementation

During the development and implementation of QMT several challenges were encountered. The large size of the project with the large number of project participants and fast track implementation schedule posed an obvious logistical challenge. This implied that very large quantities of work items were involved and the operation demanded a large number of sub-contractors, suppliers, and other players, sometimes spaced out as far as 200-km apart. The web-based QMT was extremely important in delivering information at real time to the vast number of project teams. More importantly, tracking quality performance and following up the remedial activities of the large number of subcontracts was critical. At the construction joint venture level, it was also critical to provide seamless coordination between the three levels responsible for quality – Quality engineers, Construction Supervisors and Field Inspectors. The QMT was also critical as a rapid reporting tool in responding to issues raised by the independent agent.

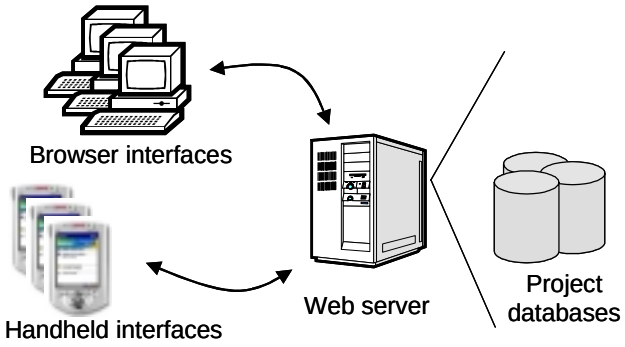

Figure 3: QMT system architecture

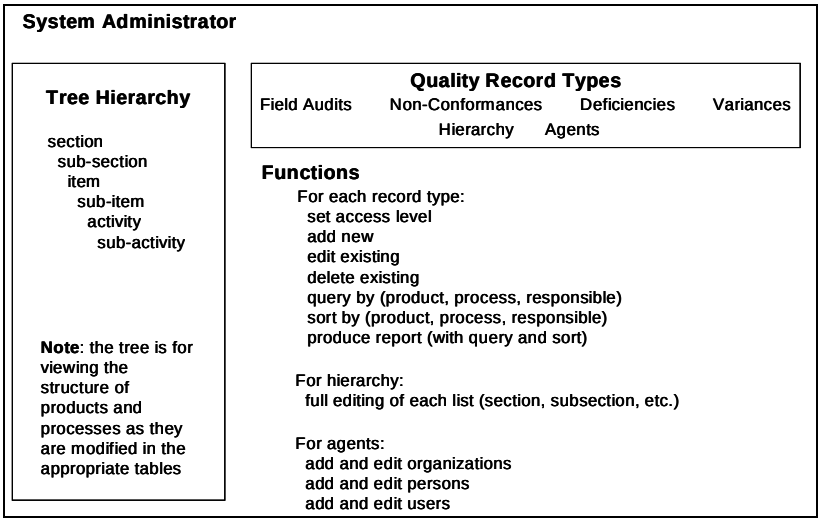

Figure 4: Functionality of the Quality Management Tool

The liaison process between the sub-contractors' operational staff and the Independent Agent was initially problematic due in part to fact that QMT was not implemented at the project start-up. The development and implementation of QMT was carried almost 2 years after contract date. This created a lag time in staff preparation and generally in lack of provisions for support in most of the Developer's operations and divisions. Efficiency was also lost from the fact that the Independent Agent did not use a similar systematic quality information system. This

resulted in mismatch in “updates” of Open Non Conformance lists that had to be reconciled through paper trails, faxes and other correspondences.

Other operational challenges included access problem. The QMT was implemented as a web-delivered tool requiring a reliable and fast access for the field personnel to download and upload update data. Most of the field offices were equipped with 56-kbps modems through the public telephone lines on shared ISP providers. This resulted in frustratingly slow access at peak hours. For field construction supervisors, access to the system was limited due to other responsibilities. With 3 to 5 site offices serving the entire project at a given time, an inspector may need to drive up 25-km away in a typical day to access QMT at the field office. Also, initially some users had the perception that the system was unnecessary “extra work”. This view was overcome by training the end users, winning clear support from upper management, and on-site demonstrations of the benefits to the Contract and Claims departments.

6. BENEFITS FROM THE QMT IMPLEMENTATION

The implementation of the QMT had a major impact on the performance and was responsible for the change in the reporting methods used by the Quality Manager to the Developers Project Management Team. These actions, coupled with improved reporting and information management by the Developer resulted in improved Quality Performance Scores and Owner’s satisfaction. Figure 5 indicates the quality performance as measured by the Independent Agent from March 1998 to November 2000. Quality performance scores improved and the amount of money forfeited as a result of low scores decreased.

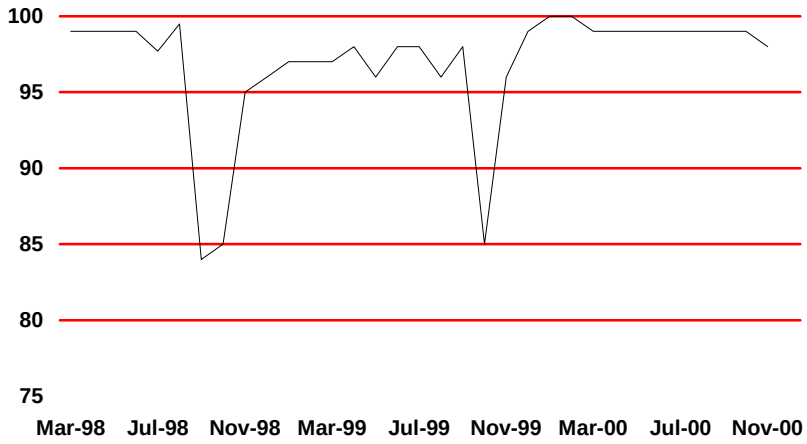

Figure 5: Quality Performance Scores after QMT Implementation

The QMT was extensively used as an effective tool for tracking progress in quality performance and for communicating the project status between various levels and project teams. Figure 6 shows typical charts generated by the Quality Manager presenting project status. The chart shows the status by the number of open deficiencies or non-conforming work items at any given time. The management and the quality management division used such status report to follow through outstanding issues and make sure they are timely and properly rectified before subsequent pay period.

Another application of QMT beyond the initial objectives was in trend analysis. Using the QMTs’ comprehensive reporting functionality, the user can quickly build a trend analysis report. The report can be partitioned based on the type of quality record (i.e., deficiency, non-conformance report, design variances, field audits), or on other indexed attributes (e.g., date opened, contract section, sub-contractor responsible, etc.). The data can also be sorted by the breakdown structure or other criteria (e.g., product, process, status, contract number). The resulting report can be exported to a spreadsheet for further analysis. Such trend analysis report can be used in monitoring subcontractors’ quality management performance. An example goal may be to identify patterns in individual subcontractors’ quality management plans and thereby work with them to improve the project delivery process.

The QMT demonstrates a practical implementation of maturing technologies. With the current trend in the IT technologies, e.g., affordable and easily accessible construction management portals, there will be more and more tools based on similar in concept to QMT (web-based collaborative environment). The scheme is most cost effective when provided as a service by a provider outside the project team. Increasingly, the industry will see service providers (for hosting, archiving and web-delivering of project data) from construction Internet portal providers. It is expected that in the near future leveraging resources of multiple portal subscribers will pave way to more cost efficient solutions.

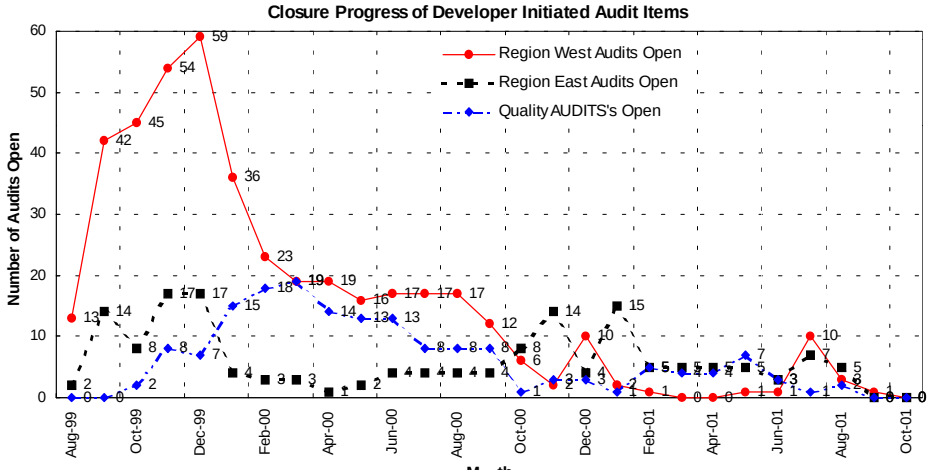

Figure 6: A Tpical Quality Performance Status Chart generated from QMT

7. CONCLUSIONS

The development and implementation of the QMT demonstrates both the direct gains of the system and the long-term applications over the facility's life cycle. This paper has contributed to the experience of the design, development and implementation of web-based collaborative project tool for managing quality. The development demonstrates a successful and practical implementation of maturing information technologies as efficient solution to the challenge of managing quality in infrastructure mega projects. The emerging trend to use web-based collaborative tools as a service during the construction and operation phases of infrastructure projects is expected to grow. Most construction Internet portal providers are currently offering this service with a variety of functionalities. It reasonable to expect in the near future, more tools based on similar web-technologies or concepts, as QMT will become available at more cost-effective solutions.

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